Illawarra Coal Dendrobium Mine

End of Panel Surface Water and Shallow Groundwater Assessment: Dendrobium Area 3B, Longwall 11

FOR

South32 - Illawarra Coal

BY

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TABLE OF CONTENTS

Executive Summary iv

1 Introduction 1
1.1 Reporting Objectives 1
1.2 Longwall 11 1

2 Surface Water and Groundwater Management 2
2.1 Surface Water Monitoring 2
2.2 Shallow Groundwater Monitoring 3

3 Subsidence 7

4 Assessment of Surface Water Quality Effects 8
4.1 Donalds Castle Creek Catchment 8
4.2 Wongawilli Creek Catchment 10
4.2.1 Subcatchment WC21 11
4.3 Lake Avon 13

5 Assessment of Surface Water Flow Effects 15
5.1 Review of Observed Data 15
5.2 Modelling Assessment 19
5.2.1 Model Selection 19
5.2.2 Data Sources 19
5.2.3 Site-by-Site Modelling and Assessment 19

6 Assessment of Shallow Groundwater Effects 29

7 Conclusions 32
7.1 Water Quality 32
7.2 Flow and Catchment 'Yield' 32
7.3 Swamps 33

8 Recommendations 33

9 References 34

Appendix A 35

Appendix B 36

Appendix C 38

LIST OF TABLES

Table 1 Summary of Surface Water TARPs – Longwall 11 v
Table 2 Surface Water Flow Monitoring Sites 2
Table 3 Summary of Swamp Monitoring 3
Table 4 Summary of Water Quality TARP exceedances for the monitoring period 8
Table 5 Summary of shallow groundwater level TARP status at *Impact Sites* 30
Table 6 Summary of shallow groundwater level TARP status at *Reference Sites*. 31
Table 7 AWBM parameters for Dendrobium catchment models 37

FIGURES

Figure 1 Monitoring Sites – Surface Water Flow 4
Figure 2 Monitoring Sites – Surface Water Quality 5
Figure 3 Monitoring Sites – 'Shallow' Groundwater 6
Figure 4 Predicted Subsidence above Area 3B (from MSEC, 2015) 7
Figure 5 Field measured Electrical Conductivity (EC) at Donalds Castle Creek (FR6) 8
Figure 6 Field measured pH at Donald's Castle Creek (FR6) 9
Figure 7 Field measured Dissolved Oxygen (DO) at Donalds Castle Creek (FR6) 9
Figure 8 Field measured EC, pH and Dissolved Oxygen at Wongawilli Creek (FR6) 10
Figure 9 Field measured pH at WC21 Pool 5, downstream of Area 3B 11
Figure 10 Dissolved iron in WC21 Pool 5, downstream of Area 3B 12
Figure 11 Dissolved iron in WC21 Pool 30, on the downstream side Longwall 11 12
Figure 12 Dissolved iron in WC21 Pool 53, upstream of Longwall 11 12
Figure 13 Field measured Electrical Conductivity (EC) at Lake Avon (LA4_S1) 13
Figure 14 Field measured pH at Lake Avon (LA4_S1) 13
Figure 15 Field measured Dissolved Oxygen (DO) at Lake Avon (LA4_S1) 14
Figure 16 Historical Flow Data – Comparison of Sandy Creek gauges and controls 16
Figure 17 Historical Flow Data – Comparison of Wongawilli Creek gauges and controls .17
Figure 18 Historical Flow Data – Comparison of Donalds Castle / Lake Avon tributaries .18
Figure 19 AWBM Rainfall-Runoff Model Flow Diagram 19
Figure 20 Comparison of Observed and Simulated Flows – DC13S1 22
Figure 21 Comparison of Observed and Simulated Flows – DCS2 23
Figure 22 Comparison of Observed and Simulated Flows – DCU 24
Figure 23 Comparison of Observed and Simulated Flows – WC15S1 25
Figure 24 Comparison of Observed and Simulated Flows – WC21S1 26
Figure 25 Comparison of Observed and Simulated Flows – WWL 27
Figure 26 Comparison of Observed and Simulated Flows – LA4 28

APPENDICES

Appendix A Water Quality Plots for all Surface Water Monitoring Sites

Appendix B Parameters used for AWBM by modelled catchment

Appendix C Assessment of Shallow Piezometer (Swamp) Behaviour

EXECUTIVE SUMMARY

This report summarises the observed, measured and estimated effects on hydrological features resulting from the extraction of Dendrobium Longwall 11.

Longwall 11 is the third panel to be extracted from Dendrobium Area 3B. Extraction began on the 18th of February 2015 and was completed on the 26th of January 2016.

The Illawarra Coal Environmental Field Team (ICEFT) conducts monitoring and inspections on landscape features including watercourses and swamps within Dendrobium Area 3B. This monitoring is conducted in accordance with the:

- Dendrobium Area 3B Subsidence Management Plan (SMP);
- Dendrobium Area 3B Watercourse Impact, Monitoring, Management and Contingency Plan (WIMMCP) (October 2015);
- Dendrobium Subsidence, Landscape Monitoring and Management Plan (Nov 2012); and
- Dendrobium Area 3B Swamp, Impact, Monitoring, Management and Contingency Plan (SIMMCP) (October 2015).

Impacts to landscape features were incorporated into the monitoring program as they were identified. The WIMMCP, SIMMCP and Landscape Trigger Action Response Plans (TARPs) form the basis of the impact assessments in this report.

Monitoring of water levels, water flow and water quality are conducted by Illawarra Coal and specialist consultants.

A total of eleven surface impacts were identified by the ICEFT. Nine of these impacts were observed on fire roads or access tracks, and two were observed within a watercourse (WC21). This assessment has identified that mining-related effects on the flow regime have occurred in tributaries to Donalds Castle Creek (DCS2, DC13S1) and a tributary to Wongawilli Creek (WC21S1) – see **Table 1**.

The Dendrobium Area 3B mine plan was modified to reduce the potential for impacts to Wongawilli Creek. No impacts have been identified in Wongawilli Creek as a result of Longwall 11 extraction. Additionally, iron staining present in the Wongawilli Creek tributary WC21 has not been detected downstream in Wongawilli Creek.

Five swamps located above Area 3 Longwalls are now at or above TARP Level 1 based on the observed groundwater level responses. These are Swamps 01a, 03, 05 (Level 3), and Swamps 01b and 08 (Level 2). These five swamps are among those listed in earlier assessment as having the potential to be affected by subsidence.

Table 1 Summary of Surface Water TARPs – Longwall 11

LW 11 SURFACE WATER TARP ASSESSMENT		CATCHMENT YIELD TARP ASSESSMENT		SURFACE WATER QUALITY TARP ASSESSMENT	
CATCHMENT	**SITE**	**TARP TRIGGER**	**REDUCTION IN TOTAL DISCHARGE***	**TARP TRIGGER**	**COMMENT**
Donalds Castle Creek	DCS2	**Level 3**	-20%	**Level 1**	Donalds Castle Creek (at FR6#); Dissolved Oxygen (DO) below TARP on one occasion
	DC13S1	**Level 2**	-15%	N/A	
	DCU	**not triggered**		N/A	
Wongawilli Creek	WC15S1	**not triggered**		**Level 2**	Wongawilli Creek (at FR6#); DO below TARP on two non-consecutive occasions
	WC21S1	**Level 1**	-11%	N/A*	Increase in pH, Iron (Fe) and Manganese (Mn) noted in WC21_Pool 5 during LW10 and LW11
	WWL	**not triggered**		N/A	
Lake Avon tributaries	LA4_S1	**not triggered**		**not triggered**	

* sometimes referred to as 'Catchment Yield' in previous End-of-Panel Surface Water Reports

FR6 = Fire Road 6. There are monitoring sites on both Wongawilli Creek and Donalds Castle Creek where they pass FR6.

1 INTRODUCTION

Illawarra Coal (IC) is required to submit regular reviews of the local hydrological data, including water quantity and quality, for watercourses and water bodies above and adjacent to Dendrobium Mine. These studies contribute to an assessment of the chemical and ecological impacts of longwall mining on surface water catchment areas, being tributaries of Lake Cordeaux and Lake Avon, and upland swamps in the Wongawilli Creek, Donalds Castle Creek and Sandy Creek catchments.

This report reviews available hydrographic and water quality data obtained for the Wongawilli Creek catchment, Upper Donalds Castle Creek catchment, and the Lake Avon sub-catchments LA4 and LA5 up to the completion of Longwall 11.

Surface water monitoring has been undertaken by IC since 2003. Field parameter measurements and sampling for more detailed laboratory chemical analyses were collected by the Illawarra Coal Environmental Field Team (ICEFT). Hydrographic gauging stations were installed and monitored by Hydrometric Consulting Services ('HCS'). Piezometers were installed and monitored by AGurba Pty Ltd.

1.1 REPORTING OBJECTIVES

This End of Panel report has been prepared to satisfy Condition 3-9 of the Approval for Dendrobium Mine (DA 60-03-2001). The objectives are to provide an end-of-panel report:

- reporting all subsidence effects (both individual and cumulative) for the panel and comparing subsidence effects with predictions;
- describing in detail all subsidence impacts (both individual and cumulative) for the panel;
- discussing the environmental consequences for watercourses, swamps, water yield, water quality, aquatic ecology, terrestrial ecology, groundwater, cliffs and steep slopes; and
- comparing subsidence impacts and environmental consequences with predictions.

1.2 LONGWALL 11

Longwall 11 was mined between 18/02/2015 and 26/01/2016. This is the third longwall completed in Dendrobium Area 3B.

This longwall had an extracted length of 2304 m and a void width of 305 m (including first workings). The minimum cutting height was 3.6 m, the average extraction height of 3.83 m, while the majority of the block was cut at 3.95 m.

2 SURFACE WATER AND GROUNDWATER MANAGEMENT

This section outlines the network of monitoring infrastructure and sites operated by Illawarra Coal at and around the Dendrobium Mine. Further details of monitoring sites and procedures are outlined in the Dendrobium Area 3B Watercourse Impact Monitoring Management and Contingency Plan (South32, 2015a).

2.1 SURFACE WATER MONITORING

Monitoring includes a selection of sites downstream and within the mining area, as well as sites located away from the mining area for comparison. Pools within streams are monitored monthly before and following mining and approximately weekly during active subsidence and in response to any observed impacts.

Figure 1 presents Longwall 11 in relation to the locations of surface water *flow* monitoring sites in Areas 3B and 3A. The surface water catchments or watersheds to the key monitoring sites (as calculated in GIS from topographic data) are also shown.

The lower pane on **Figure 1** also shows the dates of longwall progression for Longwalls 9, 10 and 11 (red dashed line and red text, expressed in DD-MM-YYY format).

A summary of these monitoring sites is presented in **Table 2**, ordered by mine area, catchment (watercourse) and then by approximate downstream order.

Table 2 Surface Water Flow Monitoring Sites

MINE AREA	HCS SITE	SITE NAME	WATERCOURSE	ALTERNATE WATERCOURSE NAME	EAST (MGA94)	NORTH (MGA94)	Catchment Area (m2)
Area 3B	300067	DC13S1	DC13	Donalds Castle Creek	289397	6194613	1,638,000
Area 3B	300068	DCS2	Donalds Castle Creek		289496	6194574	1,084,000
Area 3B	300023	DCU	Donalds Castle Creek		289396	6195538	6,219,000
Area 3B	300071	WC15S1	WC15	Wongawilli Ck tributary 15	290743	6192232	1,192,000
Area 3B	300069	WC21S1	WC21	Wongawilli Ck tributary 21	290555	6194270	2,434,000
Area 3B	300024	WWU	Wongawilli Creek		290814	6189769	3,211,000
Area 3B	300022	WWL	Wongawilli Creek		290979	6197544	20,079,000
Area 3B	300070	LA4S1	LA4	Lake Avon tributary	288138	6192567	817,000
Area 3A	300021	WC	SC6	Waratah Creek	293981	6191271	283,000
Area 3A	300026	C1	SC7	Cascade Creek	293515	6191732	775,000
Area 3A	300020	FTC	SC8	Fern Tree Creek	293846	6191848	686,000
Area 3A	300019	SC10CS1	SC10C	Banksia Creek tributary.	293358	6192433	817,000
Area 3A	300018	SC10S1	SC10	Banksia Creek tributary	293609	6192519	2,771,000
Area 3A	300025	SCU	Sandy Creek		293602	6190964	1,249,000
Area 3A	300059	SCL2	Sandy Creek		293819	6192648	7,029,000

The monitoring of water quality parameters provides a means of detecting and assessing the effects of streambed fracturing or induction of ferruginous springs. Monitoring includes measurement of field parameters such as pH, Electrical Conductivity (EC), Dissolved Oxygen (DO), Oxygen Reduction Potential (ORP) and laboratory tested analytes (DOC, Na, K, Ca, Mg, Filt. SO4, Cl, T. Alk., Total Fe, Mn, Al, Filt. Cu, Ni, Zn, Si).

Water quality monitoring sites are presented on **Figure 2** (from South32, 2015a).

2.2 SHALLOW GROUNDWATER MONITORING

Figure 3 shows Longwall 11 in relation to the locations of shallow groundwater monitoring sites in Areas 3B and 3A. Typically these sites are piezometers less than 1 m deep that monitor groundwater levels within the swamp deposits located around the Dendrobium area.

Figure 3 also shows swamp areas: broadly mapped by NSW Office of Environment and Heritage (OEH) and the site-scale mapping for Illawarra Coal carried out by Biosis.

A summary of the shallow groundwater monitoring sites is presented in **Table 3**.

Table 3 Summary of Swamp Monitoring

SWAMP	NUMBER OF PIEZO-METERS	UNDERMINED BY LONGWALLS	COMMENT
01a	9	LW9, LW10	Limited baseline data for 5 piezometers
01b	7	LW9	Limited baseline data for 5 piezometers
02	1	offset	900 m from LW9
03	1	Pillar 11/12	Response may be observed with mining LW12
05	8	LW9, LW10, LW11	Limited baseline data for 1 piezometer, insufficient recent data for 2 piezometers
07	2	offset	1.2 km from LW6
08	4	LW9, LW10 LW11	Limited baseline data for 1 piezometer, insufficient recent data for 1 piezometer
10	1	LW12	Yet to be under-mined
12	4	LW7	
13	1	LW14	Yet to be under-mined
14	2	LW15, LW16	Yet to be under-mined
15a	3	LW8, LW19	Limited baseline data for 1 piezometer, yet to be under-mined
15b	13	LW7, LW8	
22	2	Elouera Colliery	Limited baseline data
23	2	LW15, LW16	Yet to be under-mined
25	1	offset	1.4 km from LW5
33	2	offset	1 km from LW16
84	1	offset	500 m from LW5
85	2	offset	900 m from LW9
86	2	offset	3 km from LW9
87	2	Avon Colliery	Limited baseline data
88	2	Huntley Colliery	Limited baseline data
Notes:	Pink highlight for those swamps directly undermined by Longwall 11		

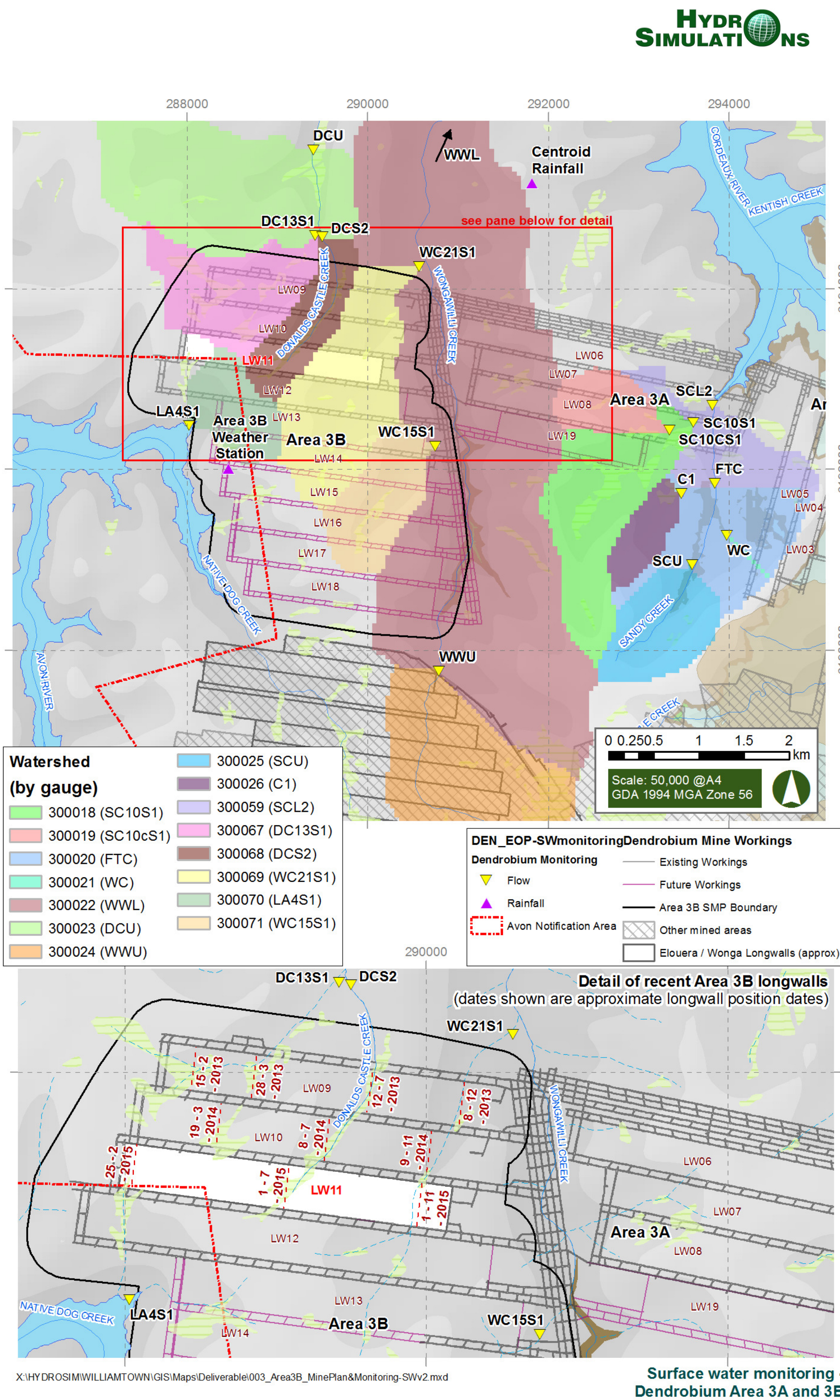
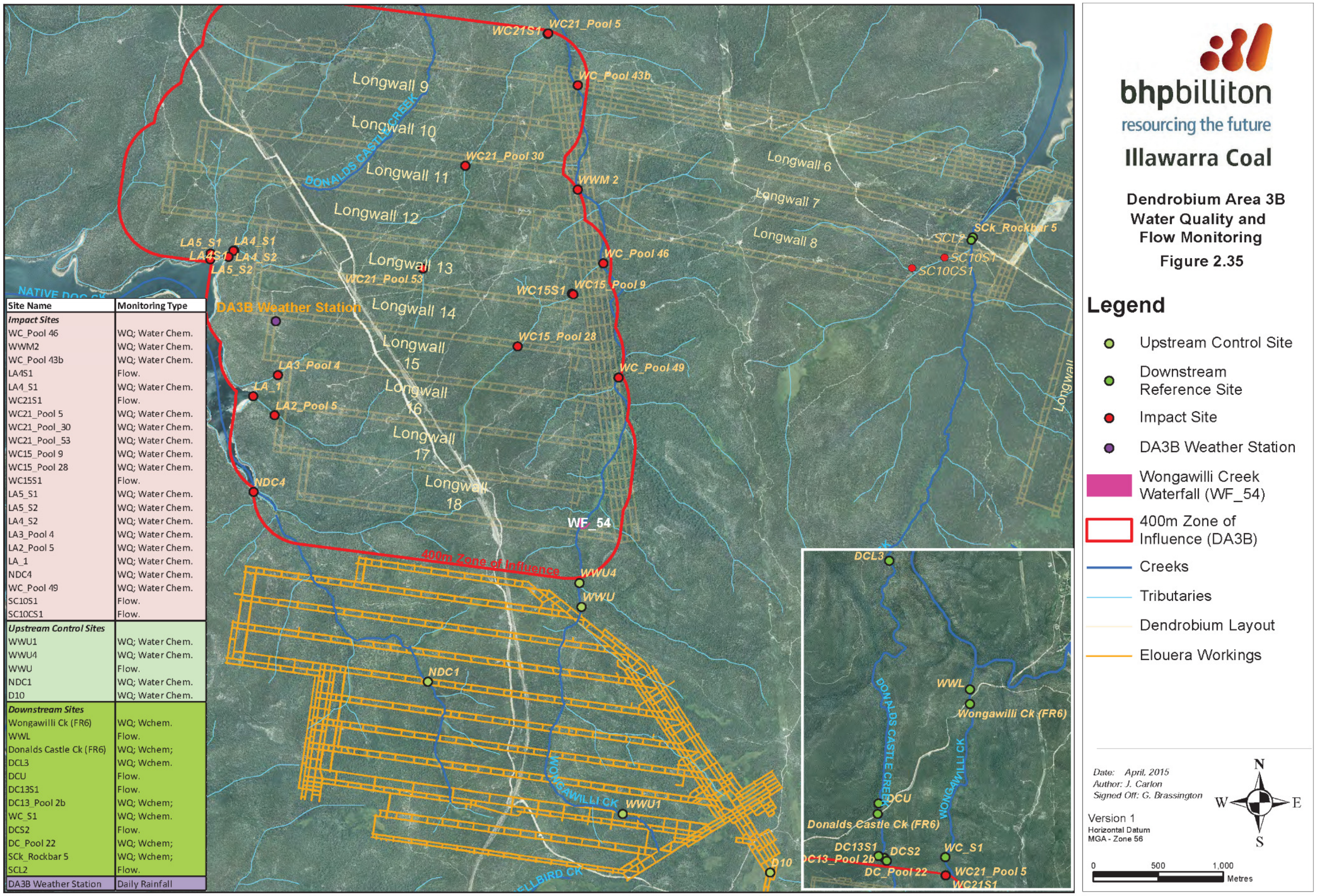


Figure 1 Monitoring Sites – Surface Water Flow



Site Name	Monitoring Type
Impact Sites	
WC_Pool 46	WQ; Water Chem.
WWM2	WQ; Water Chem.
WC_Pool 43b	WQ; Water Chem.
LA4S1	Flow.
LA4_S1	WQ; Water Chem.
WC21S1	Flow.
WC21_Pool 5	WQ; Water Chem.
WC21_Pool_30	WQ; Water Chem.
WC21_Pool_53	WQ; Water Chem.
WC15_Pool 9	WQ; Water Chem.
WC15_Pool 28	WQ; Water Chem.
WC15S1	Flow.
LA5_S1	WQ; Water Chem.
LA5_S2	WQ; Water Chem.
LA4_S2	WQ; Water Chem.
LA3_Pool 4	WQ; Water Chem.
LA2_Pool 5	WQ; Water Chem.
LA_1	WQ; Water Chem.
NDC4	WQ; Water Chem.
WC_Pool 49	WQ; Water Chem.
SC10S1	Flow.
SC10CS1	Flow.
Upstream Control Sites	
WWU1	WQ; Water Chem.
WWU4	WQ; Water Chem.
WWU	Flow.
NDC1	WQ; Water Chem.
D10	WQ; Water Chem.
Downstream Sites	
Wongawilli Ck (FR6)	WQ; Wchem.
WWL	Flow.
Donalds Castle Ck (FR6)	WQ; Wchem;
DCL3	WQ; Wchem.
DCU	Flow.
DC13S1	Flow.
DC13_Pool 2b	WQ; Wchem;
WC_S1	WQ; Wchem.
DCS2	Flow.
DC_Pool 22	WQ; Wchem;
SCk_Rockbar 5	WQ; Wchem;
SCL2	Flow.
DA3B Weather Station	Daily Rainfall

Figure 2 Monitoring Sites – Surface Water Quality

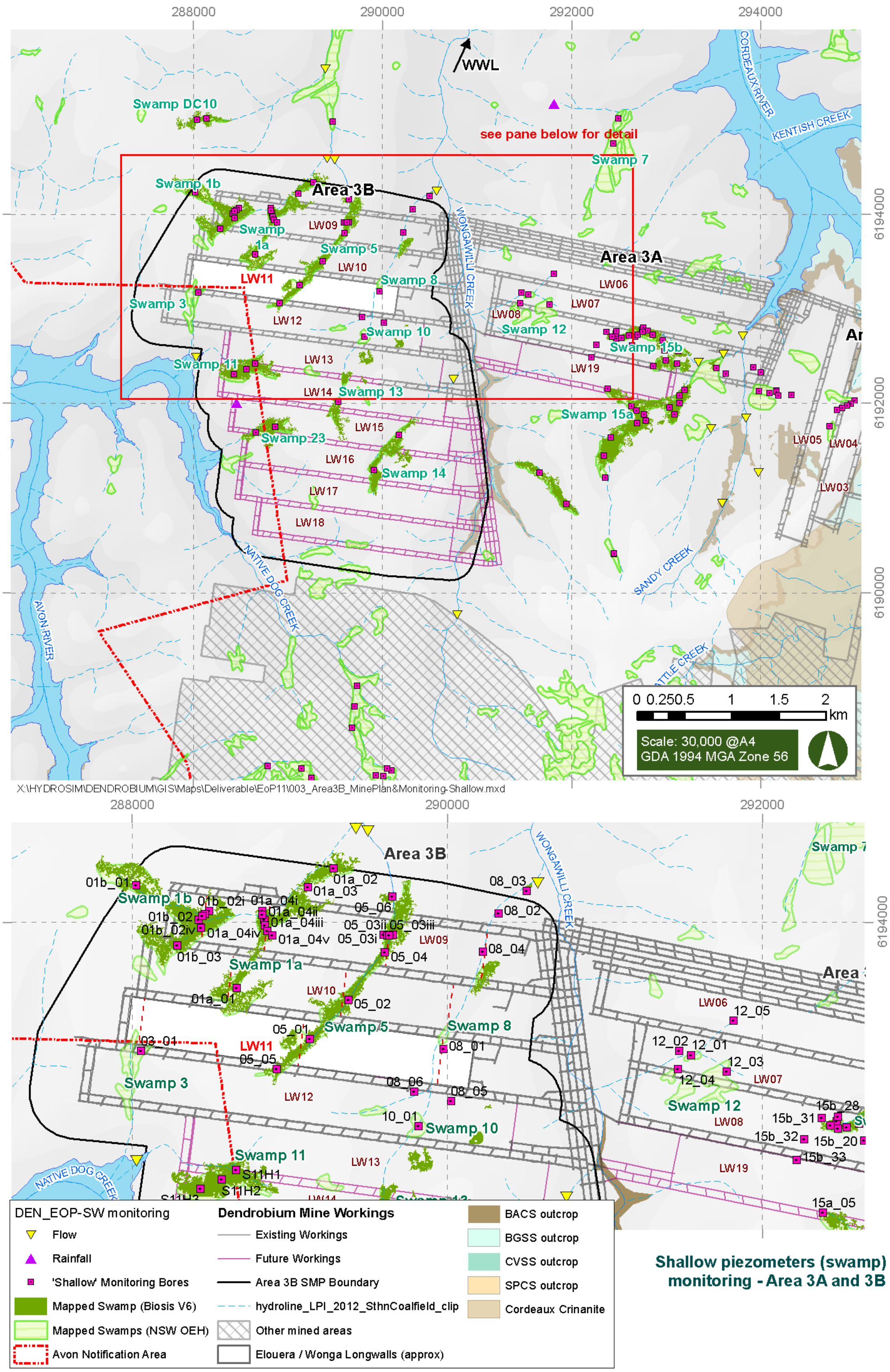


Figure 3 Monitoring Sites – 'Shallow' Groundwater

3 SUBSIDENCE

Figure 4 presents the total subsidence predicted by MSEC (2015) above Area 3B longwalls. This shows that Wongawilli Creek is outside the main area of subsidence (above the mains), although its tributaries WC21 and WC15 lie directly across the area of predicted maximum subsidence (from recent or future longwalls). The upper reaches of Donalds Castle Creek, its tributary DC13 as well as the creek LA4 lie across some or all of Longwalls 9-13, although are slightly westward of the area with the greatest predicted subsidence.

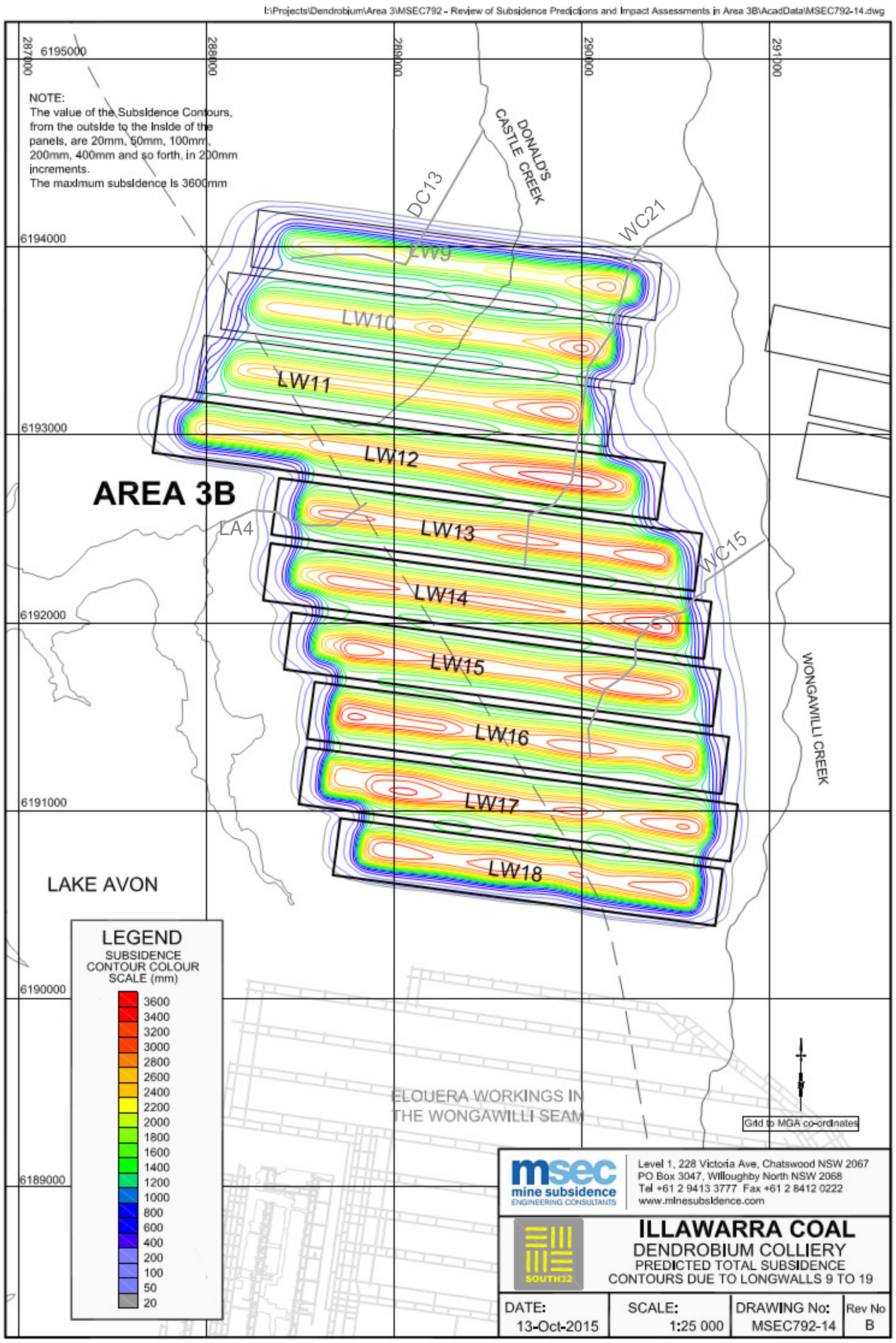


Figure 4 Predicted Subsidence above Area 3B (from MSEC, 2015)

4 ASSESSMENT OF SURFACE WATER QUALITY EFFECTS

Trigger values for water quality field parameters are defined in Attachment 1 of the Watercourse Impact Monitoring Management and Contingency Plan (South32, 2015). Trigger thresholds (TARPs) have been defined for three locations downstream of the mining area for which there is adequate high quality baseline information (Wongawilli Creek (at Fire Road 6 [FR6]) and Donalds Castle Creek (also at FR6) and Lake Avon (LA4_S1). The TARPs are based on the field parameters pH, EC and DO and defined by the value three standard deviations (SD) from the baseline mean (mean plus 3SD for EC and mean minus 3SD for pH and Dissolved Oxygen).

During the 12 month reporting period between the start of Longwall 11 (18/02/2015) and 24/02/2016, monitoring was carried out at 57 sites. Sites were monitored on an approximately weekly basis (44 monitoring events) for TARP sites Wongawilli Creek (FR6) and Donalds Castle Creek (FR6), and approximately monthly for other sites.

TARP triggers for the monitoring period are summarised in **Table 4**.

Table 4 Summary of Water Quality TARP exceedances for the monitoring period

DATE	CATCHMENT / LOCATION	PARAMETER	VALUE	TARP	TRIGGER LEVEL
23/02/2016	Donalds Castle Creek (FR6)	DO	37.5	40.1	1
13/01/2016	Wongawilli Creek (FR6)	DO	44	50.5	2
23/02/2016	Wongawilli Creek (FR6)	DO	31	50.5	

Assessment of surface water quality effects is presented by catchment (watercourse) in the following subsections. Key figures are included in the text here, while a selection of plots (hydrographs) is available for all sites in **Appendix A**.

4.1 DONALDS CASTLE CREEK CATCHMENT

Time series plots of key field parameters measured at Donalds Castle Creek at FR6 are shown in **Figure 5**, **Figure 6** and **Figure 7**.

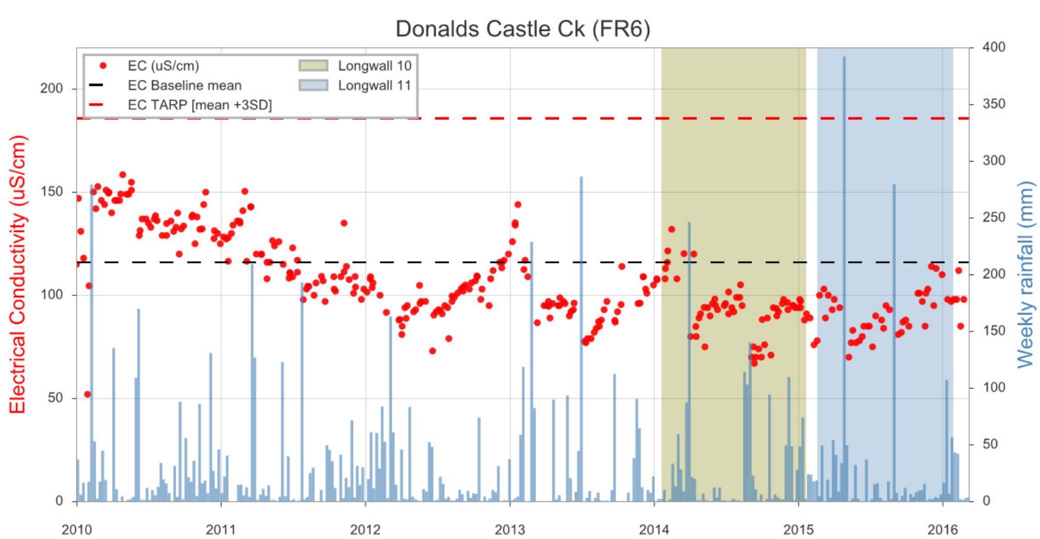


Figure 5 Field measured Electrical Conductivity (EC) at Donalds Castle Creek (FR6)

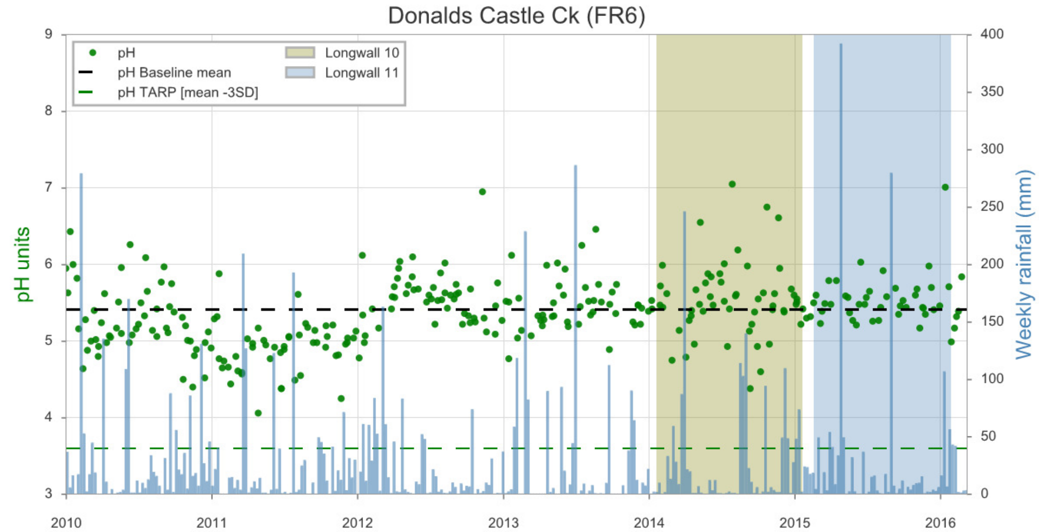


Figure 6 Field measured pH at Donald's Castle Creek (FR6)

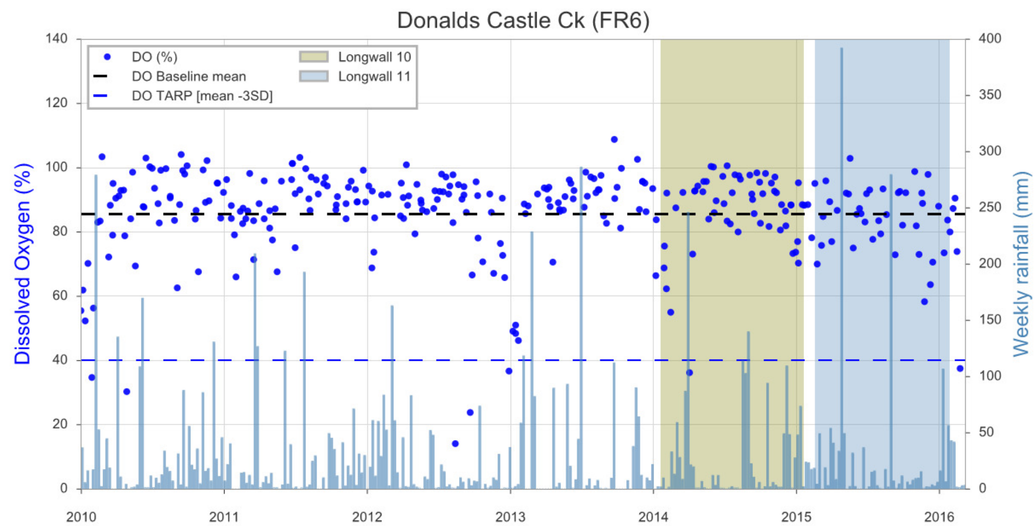


Figure 7 Field measured Dissolved Oxygen (DO) at Donalds Castle Creek (FR6)

At the Donalds Castle Creek site (at FR6), the TARP for DO was triggered on one instance on the 23/02/2016, representing a Level 1 Trigger.

Given that the TARP trigger levels are based on a statistical measure of baseline variability it is expected that the threshold would be exceeded from time to time without significance. The key field parameters showed no other adverse trends during the monitoring period and the records are considered to show no water quality impacts from mining.

4.2 WONGAWILLI CREEK CATCHMENT

Plots of key field parameters from Wongawilli Creek at FR6 are shown in **Figure 8**.

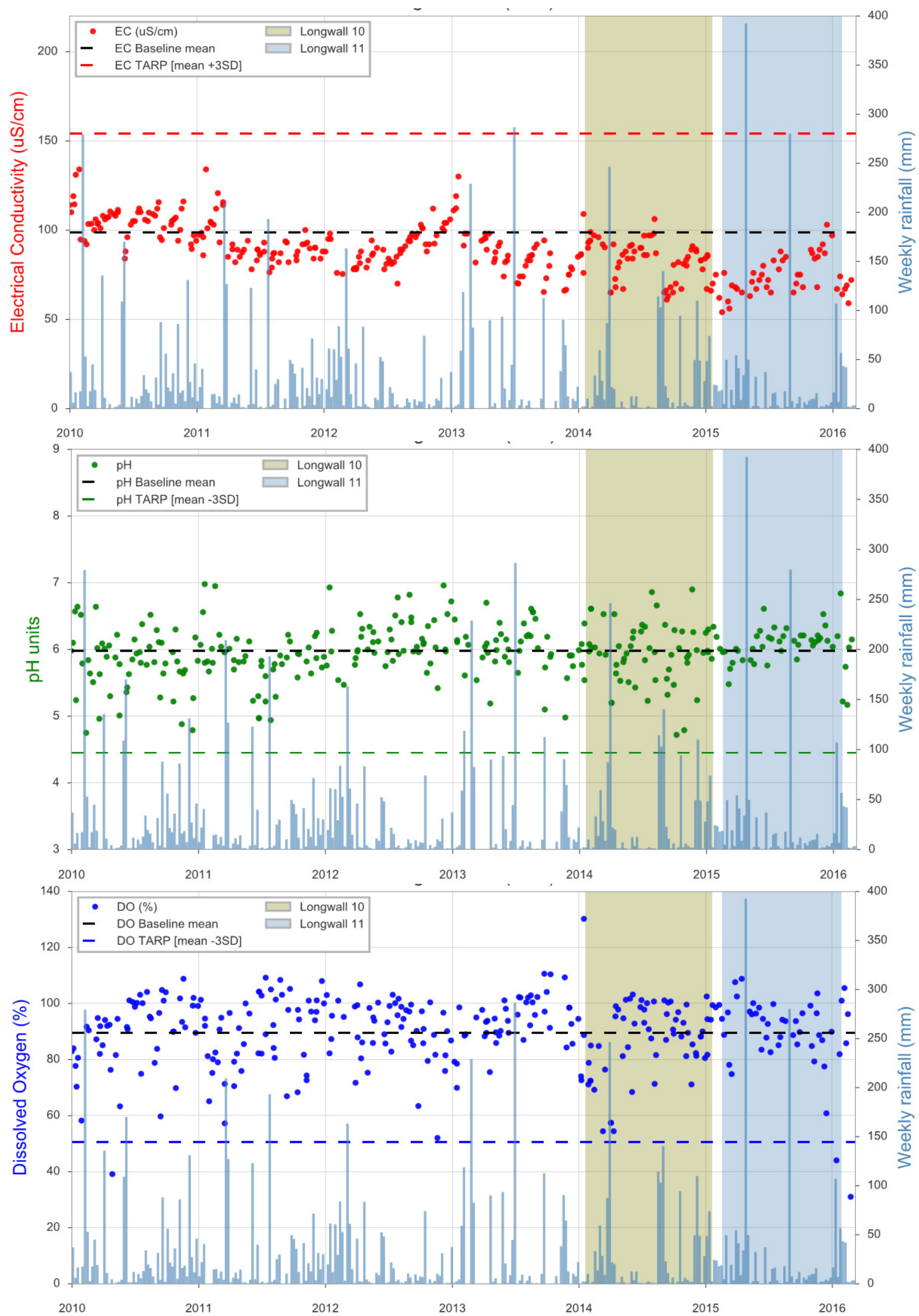


Figure 8 Field measured EC, pH and Dissolved Oxygen at Wongawilli Creek (FR6)

At the Wongawilli Creek site (at FR6), the TARP level for DO was triggered on two occasions on the 13/01/2016 and 23/02/2016. The exceedances are non-consecutive and represent a Level 2 Trigger.

The key field parameters show no other adverse trends during the monitoring period and the records are considered to show no water quality impacts from mining at this location. A Level 2 TARP trigger requires review of the monitoring frequency. In this case the current weekly frequency is considered appropriate.

4.2.1 SUBCATCHMENT WC21

The DA3B Longwall 11 End of Panel Landscape Report (South32, March 2016) identified surface cracking at two locations in the WC21 creek bed (identified as WC21-DA3B_LW11_008 and DA3B_LW11_010). The two locations are within the zone of influence for Longwall 10 and Longwall 11. The fractures are consistent with a Level 1 impact being less than 100 mm in width and 10 m in length with no observable loss of surface water or erosion. Water quality data for catchment WC21 monitored at locations upstream (WC21_Pool 53) and downstream of Longwall 11 (Pool 30 and Pool 5) are discussed below.

Monitoring location WC21_Pool 5 is located downstream (to the north) of mining Area 3B. Although the Electrical Conductivity of water at this location has remained within the baseline range, water pH has shown an increase since the start of Longwall 10 (**Figure 9**). Water pH at this location showed similar elevated values during the reporting period. While the values remain within the natural range for all sample locations (pH 3.2-7.1), the trend is anomalous compared with pre-Longwall 10 conditions.

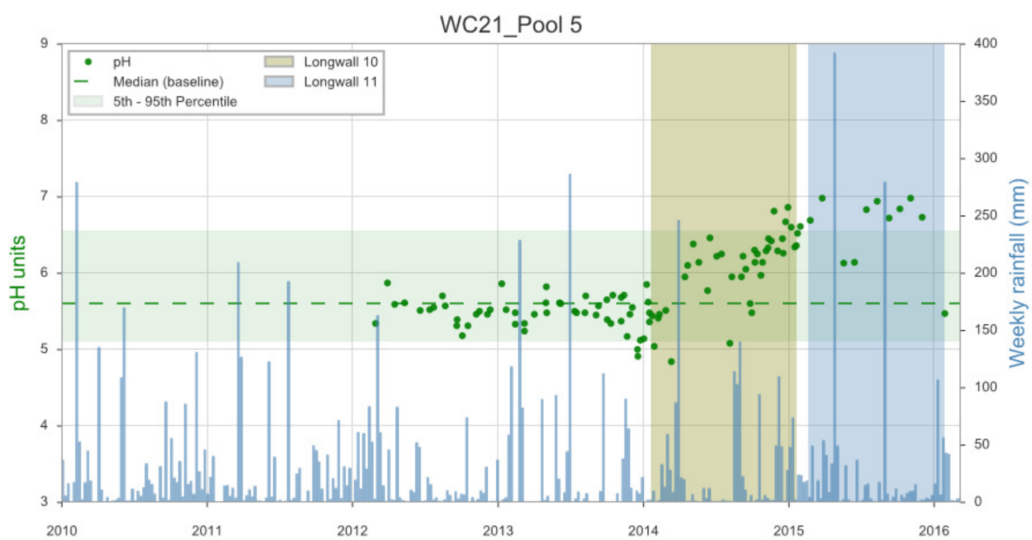


Figure 9 Field measured pH at WC21 Pool 5, downstream of Area 3B

The increase in pH at WC21 Pool 5 coincides with an increase in dissolved iron (and manganese) during Longwall 10 and Longwall 11 (**Figure 10**). Measurements of dissolved iron in Pool 5 peaked at 1.48 mg/L during Longwall 11, significantly above the pre-Longwall 10 mean of 0.09 mg/L (pre-Longwall SD = 0.09), and significantly above the range observed at upstream locations Pool 30 (**Figure 11**) and Pool 53 (**Figure 12**). The measured concentration of dissolved iron in Pool 5 returned to levels at, or below 0.25 mg/L from November 2016.

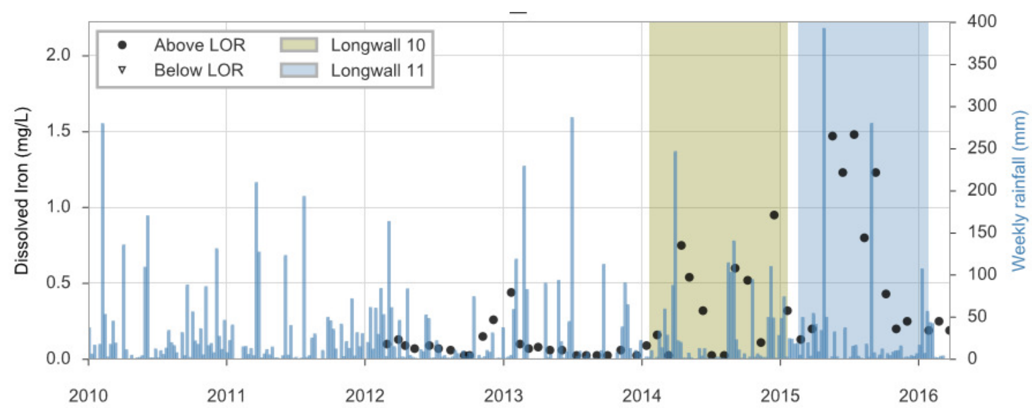


Figure 10 Dissolved iron in WC21 Pool 5, downstream of Area 3B

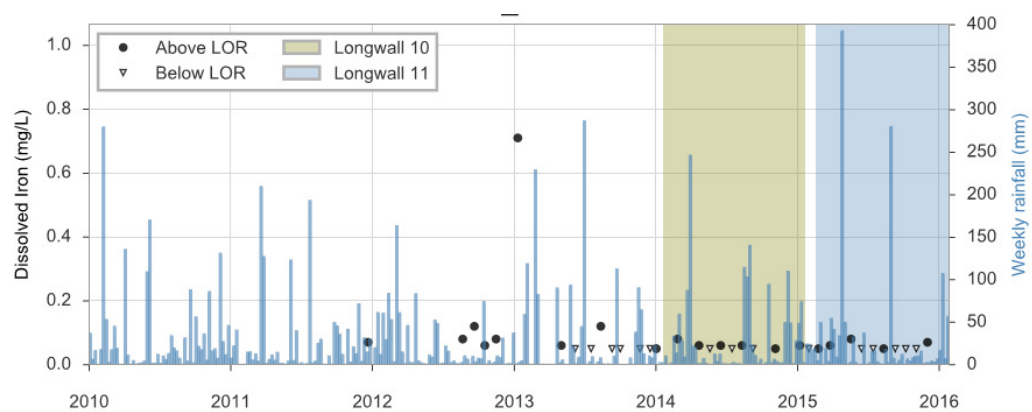


Figure 11 Dissolved iron in WC21 Pool 30, on the downstream side Longwall 11

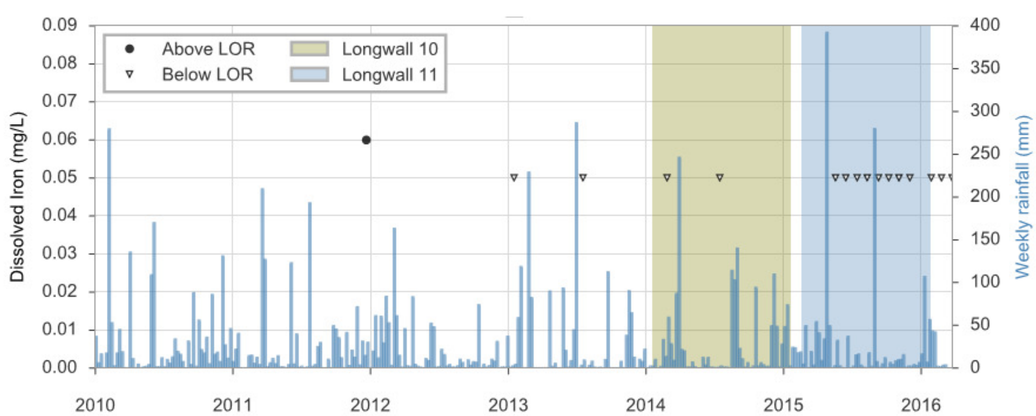


Figure 12 Dissolved iron in WC21 Pool 53, upstream of Longwall 11

In summary, assessment of water quality at WC21 Pool 5 indicated anomalous trends in pH, dissolved iron and dissolved manganese that coincide with mining of Longwalls 10 and 11. The anomalous trends are not evident at locations immediately downstream of Longwall 11, nor at locations upstream of Longwall 11. The concentration of dissolved iron in Pool 5 declined from November 2015, which is approximately the time the watercourse was undermined by Longwall 11.

The effect seen at WC21_Pool 5 was not evident in Wongawilli Creek at site WC_S1 which is located approximately 500 m downstream of the confluence between WC21 and Wongawilli Creek (**Figure 2**).

4.3 LAKE AVON

Time series plots of key field parameters measured at LA4_S1 near Lake Avon are shown in **Figure 13**, **Figure 14** and **Figure 15**.

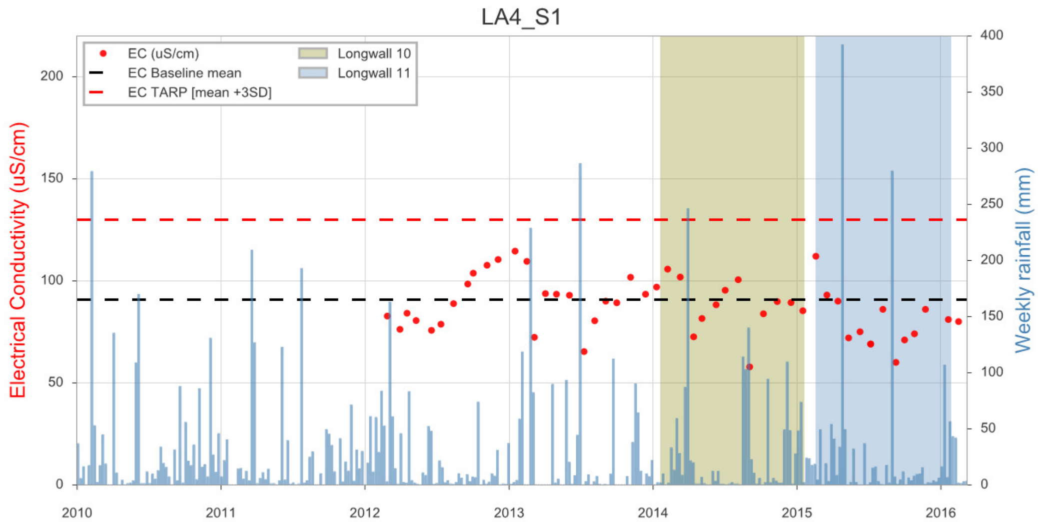


Figure 13 Field measured Electrical Conductivity (EC) at Lake Avon (LA4_S1)

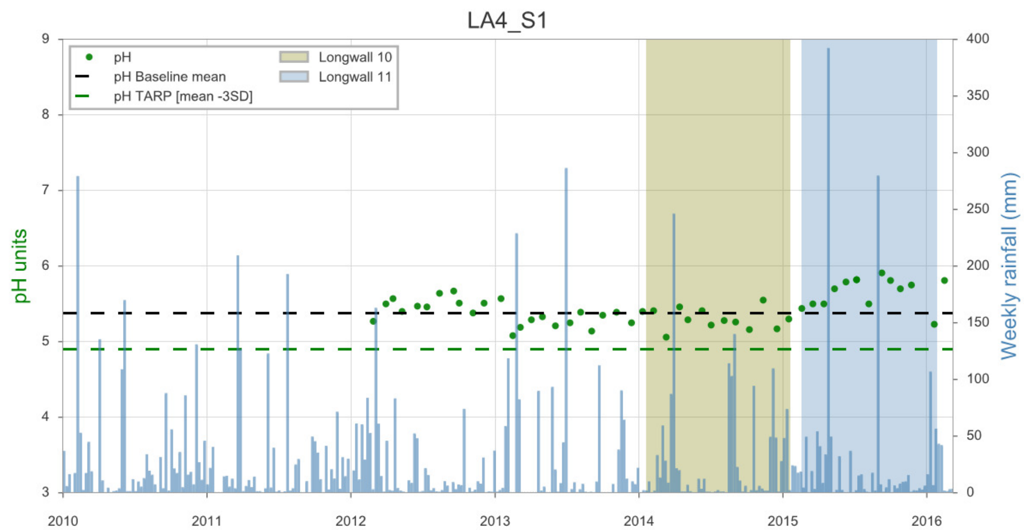


Figure 14 Field measured pH at Lake Avon (LA4_S1)

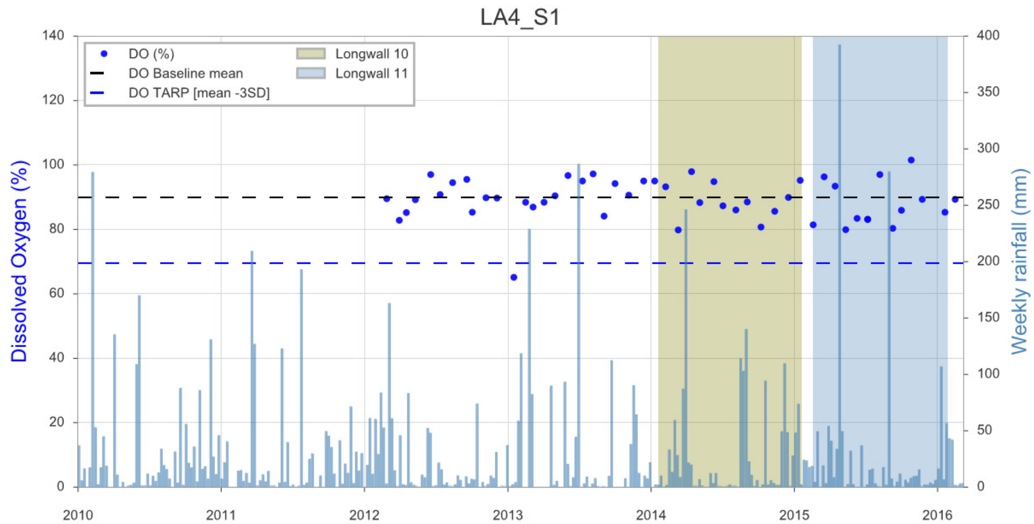


Figure 15 Field measured Dissolved Oxygen (DO) at Lake Avon (LA4_S1)

At LA4_S1, no TARP levels were triggered during the reporting period. **Figure 14** shows a mild increase in pH (from about 5.5 to 6) during Longwall 11. The increase in pH was not accompanied by significant changes in dissolved metal concentrations.

Overall the key field parameters show no other adverse trends during the monitoring period and the records show no water quality impacts from mining at the Lake Avon sites.

5 ASSESSMENT OF SURFACE WATER FLOW EFFECTS

Effects on surface water hydrology were previously assessed by calibrating a water balance model, RUNOFF-2005 (van de Griend *et al*., 2002; Ecoengineers, 2011, 2012a, 2012b, 2013, 2015) to stream flow data for the main monitoring sites around Dendrobium. A similar approach has been adopted in this End of Panel report. However, two differences in the analysis and reporting are:

- as a precursor to modelling, a review of flow data has been conducted (**Section 5.1**);
- the AWBM rainfall-runoff model has been utilised in place of the RUNOFF2005 code (**Section 5.2**).

5.1 REVIEW OF OBSERVED DATA

Ecoengineers (2015) provide background to the monitoring data, including the rating of flow and the maximum reliable flow at each site.

For each watercourse and flow gauges of primary interest, the historical flow record has been plotted alongside the record from a nearby ‘control’ gauge (i.e. a gauge that was not undermined at all or not undermined during the period of interest). The hydrographs are shown on the following figures:

- - Sandy Creek (Area 3A);
- **Figure 17** - Wongawilli Creek (Area 3B and 3A);
- **Figure 18** - Donalds Castle Creek and Lake Avon (Area 3B).

The flow records are shown as log (upper chart) and natural scale (low flows – second chart) on each figure and were inspected for apparent changes in character, with the rainfall and rainfall trend and longwall timing presented alongside. The flow records were then inspected to attempt to identify deviation from the pre-mining behavior. This comparison proved inconclusive and further comparison was made.

The ratio of daily flow in each of the assessment points versus that in the relevant control site was calculated and is plotted on the lower chart on each figure. A comparison of the relative catchment area to the sites is also included on the chart, which provides context for what the approximate flow ratio should be, assuming similar geological, topographical and rainfall characteristics (which are assumed to be constant between assessment points and controls).

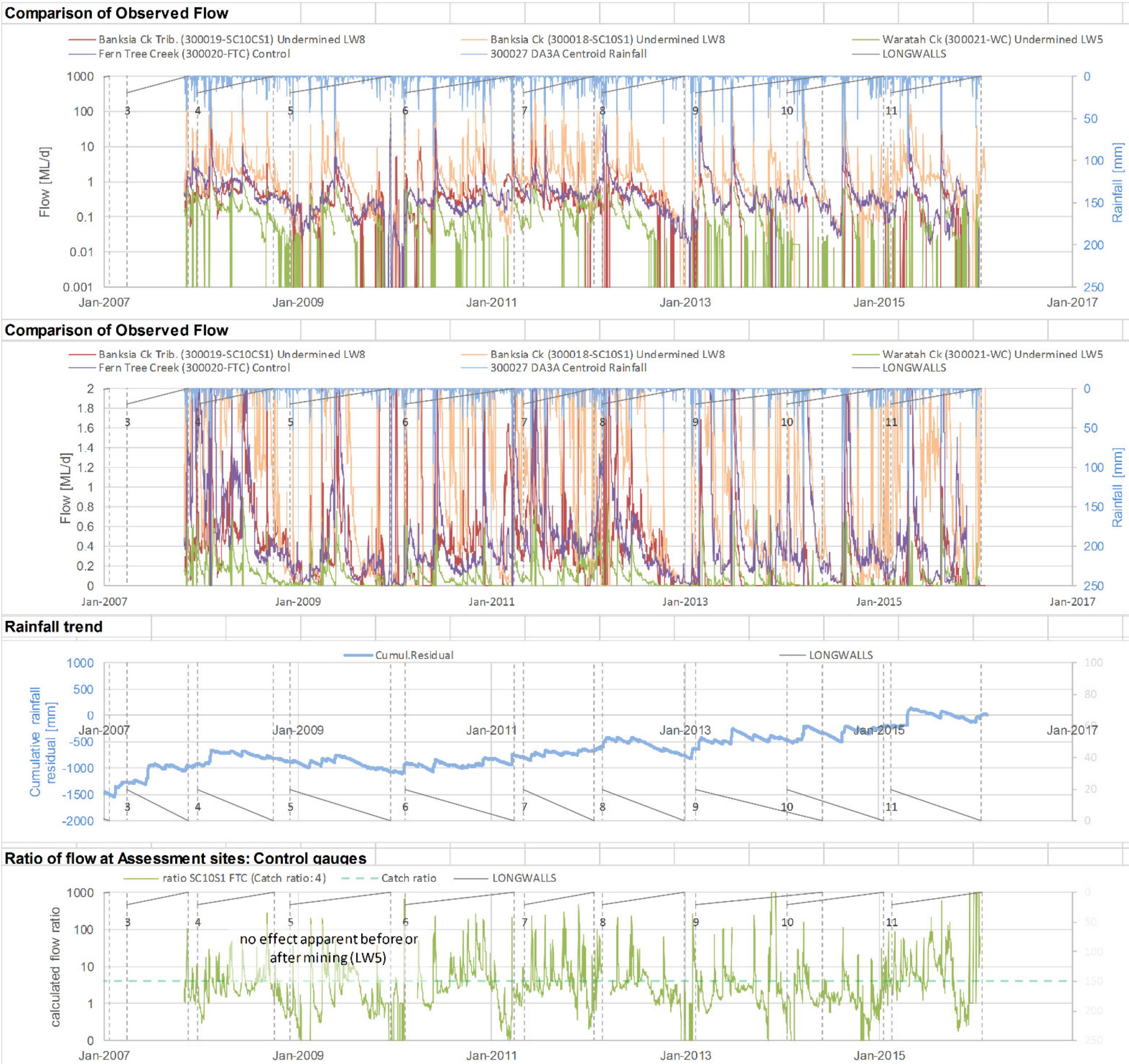


Figure 16 Historical Flow Data – Comparison of Sandy Creek gauges and controls

There is no discernible effect or change in behaviour on Sandy Creek when considering flows in Fern Tree Creek ('FTC') as the control site (**Figure 16**), either during Longwall 11 (unsurprising given that Sandy Creek is remote from Area 3B) or during the extraction of earlier longwalls.

There is no discernible mining-related reduction in flow on Wongawilli Creek ('WWL') when considering flows in upper Wongawilli Creek ('WWU') as the control site (see green series at the bottom of **Figure 17**), either during Longwall 11 or during the extraction of earlier longwalls.

There is an apparent reduction in flow on Wongawilli Creek Tributary 21 ('WC21') when considering flows in upper Wongawilli Creek (WWU) as the control site (red series at the bottom of **Figure 17**). This effect is seen as a reduction in flow midway through Longwall 9 and into Longwall 10. Such an effect is not as clear late in Longwall 10 or early Longwall 11 suggesting that flow at this site may have recovered somewhat toward pre-mining conditions. The observed data is spiky, so there might be a similar reduction late in Longwall 11, or it may just be 'noise' in the data. If recovery has occurred, then the implication is that the temporary change in flow was due to increased porosity and dilation of shallow strata .

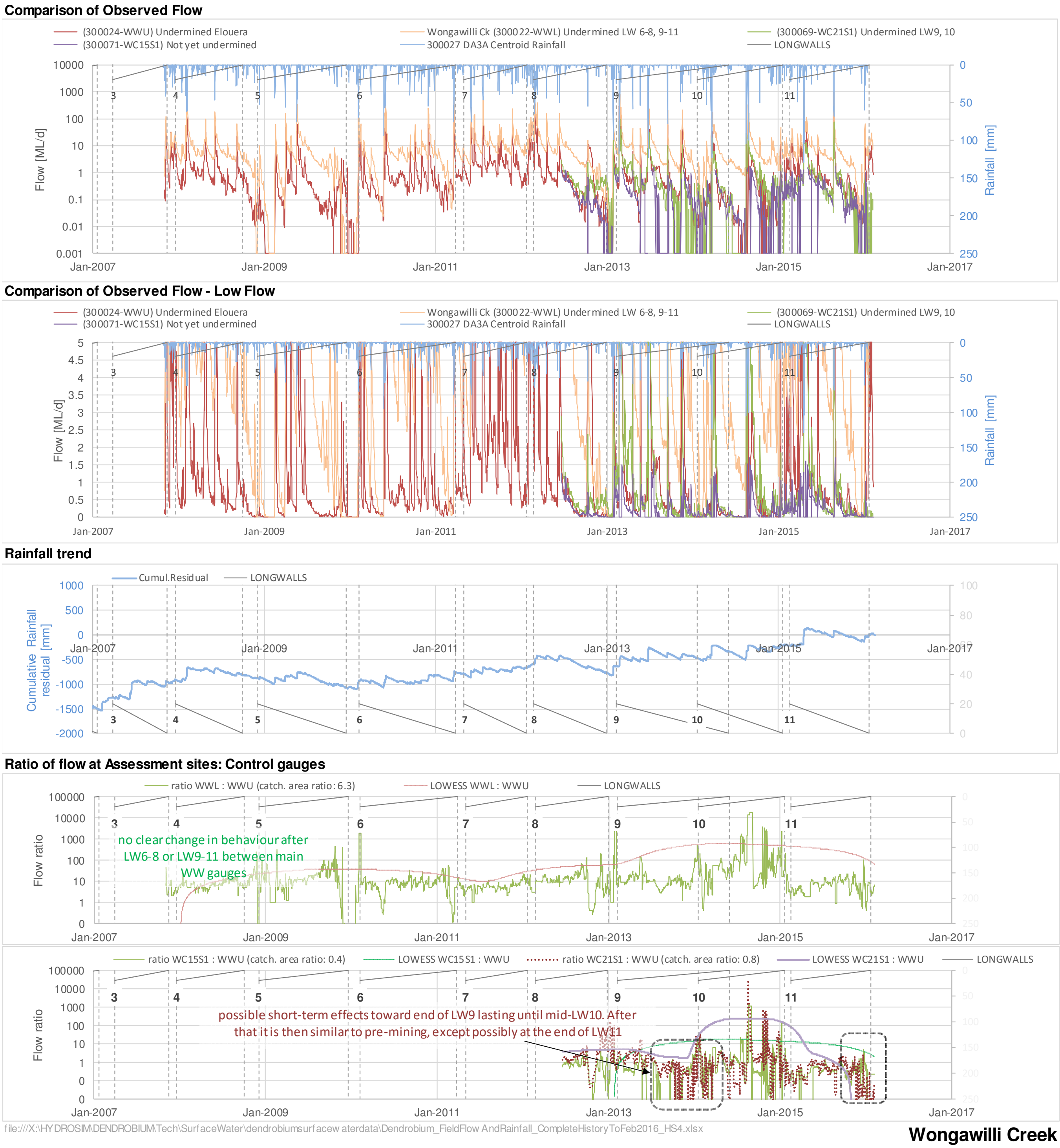


Figure 17 Historical Flow Data – Comparison of Wongawilli Creek gauges and controls

WC15 has not yet been directly undermined. The green series on the bottom chart of **Figure 17** suggests that no effects are discerned that can be clearly related to the longwall schedule.

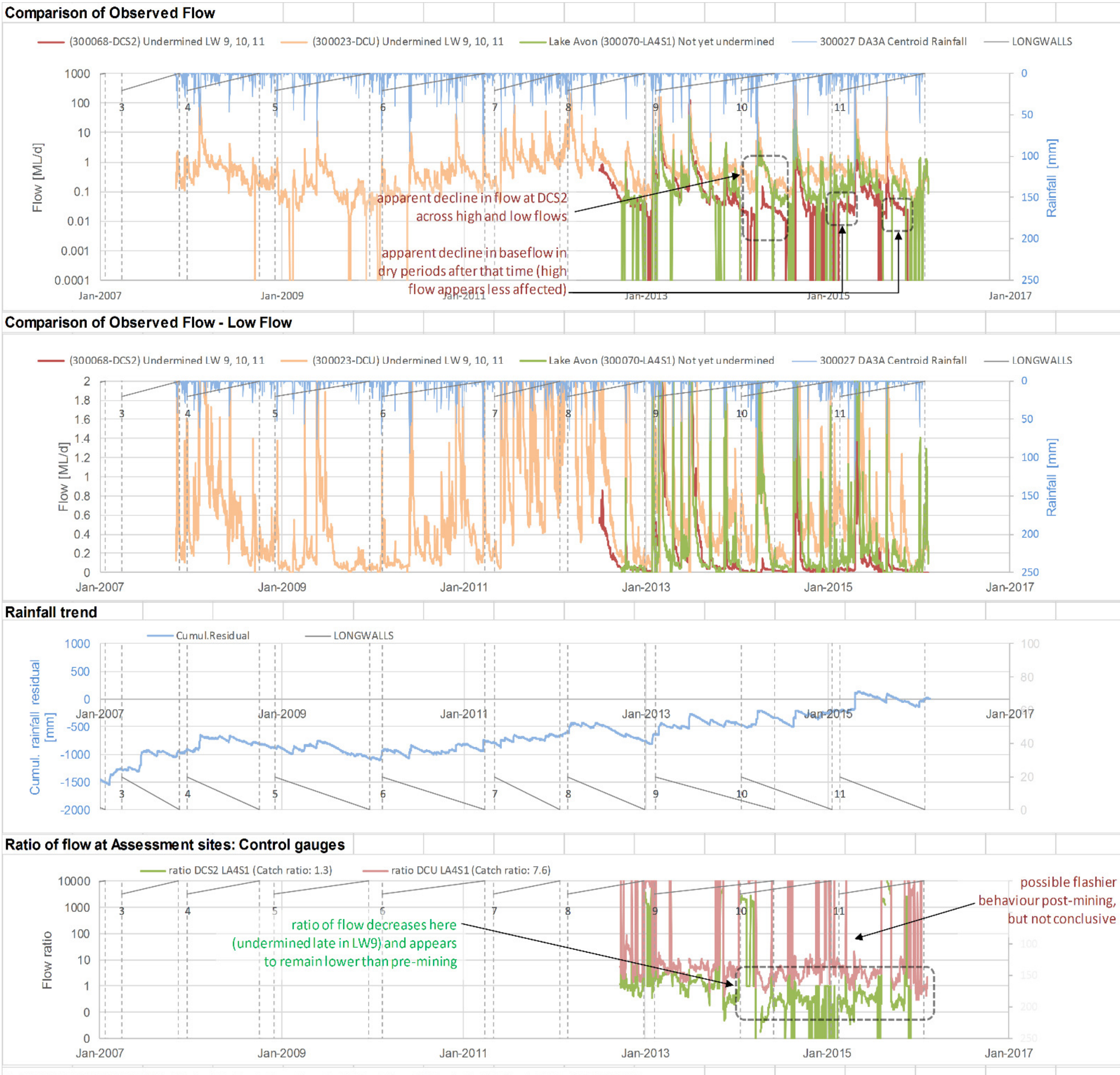


Figure 18 Historical Flow Data – Comparison of Donalds Castle / Lake Avon tributaries

There is no discernible mining-related reduction in flow on Donalds Castle Creek ('DCU') when considering flows in the Lake Avon tributary ('LA4S1') as the control site, either during Longwall 11 or during the extraction of earlier longwalls.

There is an apparent reduction in flow on Donalds Castle Creek Tributary 2 ('DCS2') when considering flows in Lake Avon tributary ('LA4S1') as the control site. This effect is seen as a reduction in flow either late in Longwall 9 or at the beginning of Longwall 10. This effect remains apparent throughout the period of Longwall 11.

5.2 MODELLING ASSESSMENT

5.2.1 MODEL SELECTION

As stated previously, the widely-used and accepted rainfall-runoff code AWBM has been adopted for this assessment. This is slightly different to the RUNOFF code used previously (by Ecoengineers), however the concepts are quite similar.

AWBM was first developed by W. Boughton in the early 1990s (Boughton and Chiew, 2003). The model takes average rainfall and potential evaporation across a catchment as inputs on a daily timestep. The user provides parameters to describe the relative area and soil moisture storage capacity of three stores covering the catchment (**Figure 19**). Based on these inputs and parameters, surface runoff and baseflow are calculated and then released from the relevant storage using a linear decay (*Ksurf* or *Kbase*). These decayed flows are summed to estimate total catchment outflow on a daily basis.

Most of the parameters relate in part to the simulated connected groundwater system in the catchment.

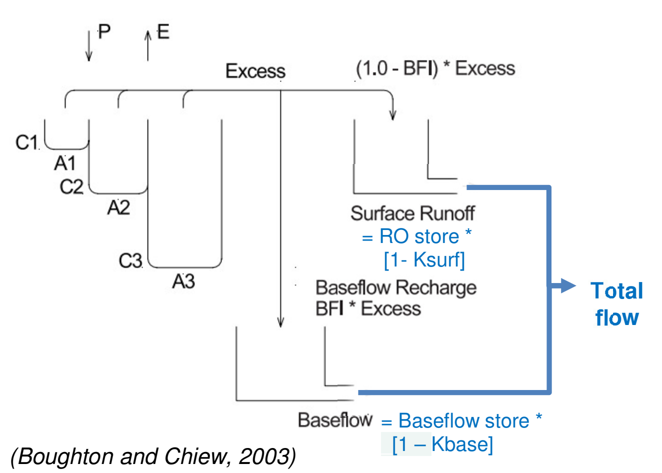


Figure 19 AWBM Rainfall-Runoff Model Flow Diagram

For this project, AWBM has been populated and run through the eWater 'Source' platform (eWater, 2012).

5.2.2 DATA SOURCES

Rainfall and potential evaporation inputs were obtained from SILO[1] for the location in which Dendrobium lies.

Catchment areas were calculated in GIS from LiDAR data (**Figure 1**) and compared against the catchment areas provided by Illawarra Coal. The GIS catchment area has been used in the AWBM models.

Daily flow from each of the monitoring sites has been used to calibrate the respective Source catchment model. Some sites have flow data from late 2007, while others have data covering the last few years.

5.2.3 SITE-BY-SITE MODELLING AND ASSESSMENT

An AWBM model was constructed for each of the sites listed in **Table 2**. Calibration was carried out manually, focussing on 'history-matching' of observed and modelled flows during the pre-mining period at each monitoring site. Model calibration was carried out with the focus on simulating recession and low-flow periods. Observed flow data was generally used as is, including data that was above the 'Maximum valid flow' reading for each gauging station as

[1] https://www.longpaddock.qld.gov.au/silo/about.html

discussed in Ecoengineers (2015) – because of the subsequent focus on recessions to assess the occurrence of mining effects, this is not considered an issue.

The model has been run continuously for the period 1985 to March 2016, which easily covers the period of the observed flow record and minimises any error associated with estimates of antecedent soil moisture conditions.

The adopted parameters for the AWBM models are provided in **Appendix B**.

Once the model was calibrated to an appropriate degree, the flow during the subsequent ‘post-mining’ period plus specific sub-period covering the extraction of Longwall 11, was predicted while holding all parameters constant.

The predicted post-mining flows were compared against observed flows. Differences in the pre- and -post-mining period are then highlighted and used to infer and quantify any effects that mining has had on the catchment. The assessment of observed flow data (**Section 5.1**) and surface water quality (**Section 4**) were referred to in order to check the findings from the rainfall-runoff modelling. The critical behaviour that is investigated is whether, having achieved a good calibration for the pre-mining period, the recession limbs on the observed flow hydrograph in the post-mining periods fall consistently below the modelled hydrograph. This behaviour would suggest a reduction in flow in that sub-catchment.

The figures presented for each modelled catchment are the same as the following list, and in order to make the assessment as concise as possible, only the key features of the four charts are listed for each catchment in this same format:

A) is a correlation of observed and modelled flows, with the pre-mining calibration period presented as one series, and all the post-mining period presented as another. In some cases, a third series, also pre-mining, may also be used in order to check whether any inferred mining effects are transient (non-permanent).

B) is a comparison of the calculated flow duration curve for observed and modelled flows for pre-mining (calibration) and post-mining periods, including the Longwall 11 sub-period.

C) presents a comparison of modelled and observed flow hydrographs, with longwall progression and undermining dates for context. The hydrograph is on a log-scale to allow easier comparison of flows at the lower end of the scale.

D) presents a ratio of the modelled and observed flows as a timeseries, in order to provide a graphical estimate of any effect of mining on catchment outflow.

Some further comments are that Chart A (the scattergram) shows R^2 (the “coefficient of determination”) as a measure of correlation. Previous End of Panel Assessments relied on the Nash-Sutcliffe coefficient to describe the fit between observed and modelled flows. While R^2 is presented here, it is a guide only – HydroSimulations has relied far more heavily on the visual comparison of the scattergram (Chart A), the flow duration curves (Chart B), and the hydrographs (Charts C and D), alongside a comparison of the mean modelled flow and mean observed flow in the pre-mining period, to judge calibration.

Assessment against Catchment Water Balance TARP

Ecoengineers (2015) describes the definition of three TARP levels for catchment water balance:

“These were set based on the agreement between observed rainfall (Pobs) and modelled or simulated catchment discharge (Psim = Qsim + ETsim) as established by hydrologic modelling of the Pobs and Qobs for the (annualized) aggregates of all validly gauged period pre- and (separately) post-mining periods respectively:

- Level 1: a change in measured discharge (between pre- and post-mining) 6-12% less than average annual precipitation;
- Level 2: a change in measured discharge (between pre- and post-mining) 12-18% less than average annual precipitation;
- Level 3: a change in measured discharge (between pre- and post-mining) >18% less than average annual precipitation."

The calculation of TARP is sensitive to the inputs, including the SILO-estimated actual evapotranspiration (ET) and the inclusion of flows above the maximum reliable flow. Therefore, HydroSimulations has calculated the TARPs, but also made comment on any change in flow based on comparison of modelled and observed flows.

DC13S1 – Donalds Castle Creek

This creek lies across the centre of several Area 3B panels (**Figure 1**). The catchment to DC13S1 was first undermined at the commencement of Longwall 9, has been undermined by Longwall 10 and by part of Longwall 11, but will not be undermined by future longwalls.

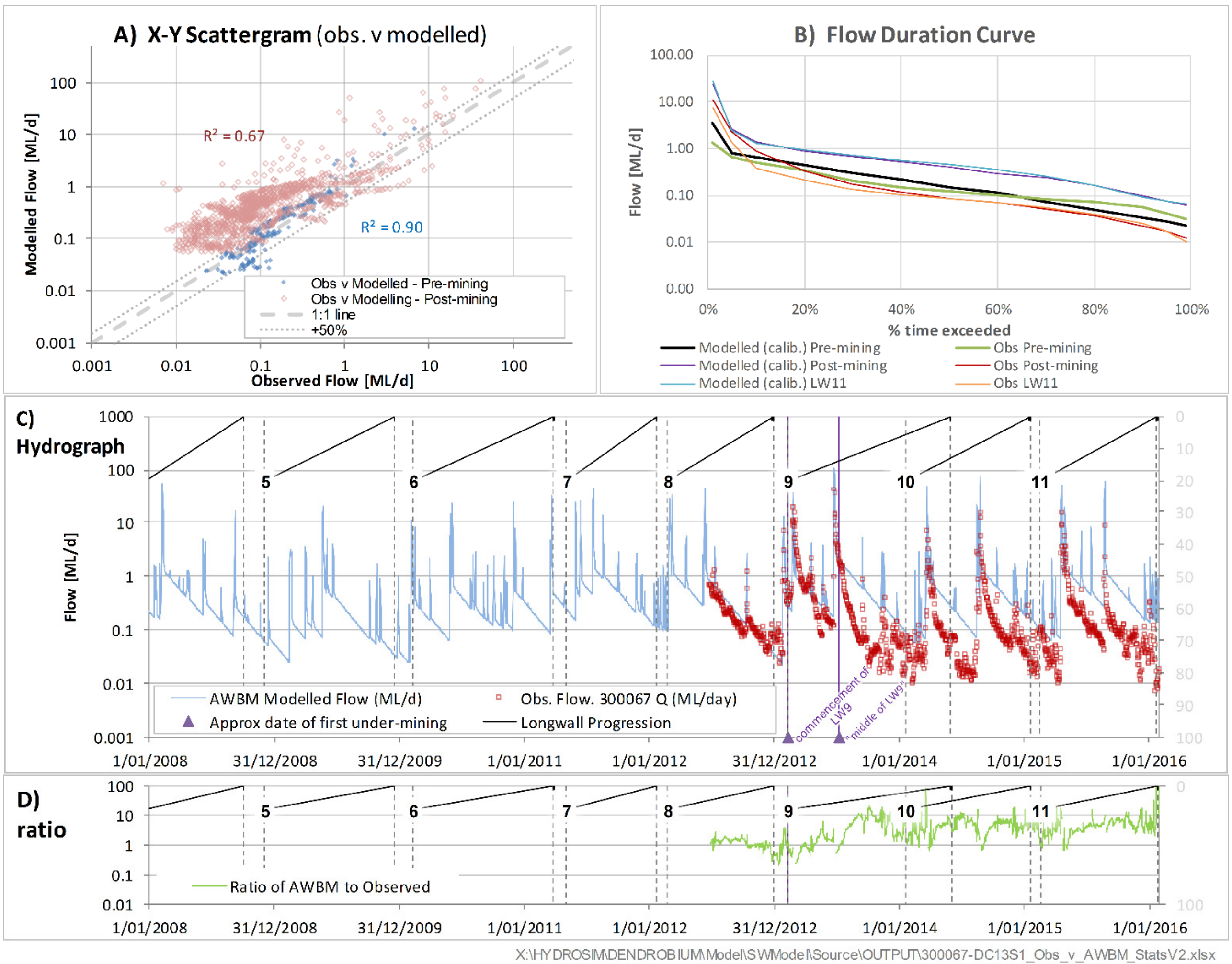


Figure 20 Comparison of Observed and Simulated Flows – DC13S1

A	The scattergram shows that during the pre-mining period the model is a good fit to observed data, as shown by the graphical correlation to the 1:1 line and also the R^2. This fit declines significantly when the post-mining period is considered.	
B	Confirms the good match between modelled and observed flows for the pre-mining period, and illustrates that the model over-estimates flow for the subsequent post-mining period, including throughout Longwall 11.	
C	The hydrograph shows a very good match between observed flows up until July 2013 (mid-way through Longwall 9). The full range of flows is quite well matched, including the recessions. Initial undermining by Longwall 9 did not affect the fit, but the fit declines significantly midway through Longwall 9, and from then on the observed hydrograph remains consistently below that predicted by the model, except during the heaviest of rainfall events.	
D	The pre-mining ratio of modelled to observed flows shows the ratio hovers at about 1, with deviation during short-term high flow events. The post-mining ratio oscillates around 4-10 from the middle of Longwall 9 to the end of Longwall 11.	
Assessment:	Stream flow characteristics and sub-catchment yield as measured at DC13S1 appear to have been affected as a result of undermining of the watercourse midway through Longwall 9. The effect continues through Longwalls 10-11.	
Catchment discharge for Longwall 11:	**TARP LEVEL 2**	Water balance [Qsim + ETsim] is 15% below average Pobs.

DCS2 – Donalds Castle Creek

As shown on **Figure 1**, this creek lies across the centre of several Area 3B panels. The catchment to DCS2 was first undermined by Longwall 9 (in early July 2013), has been undermined by both Longwall 10 and 11, and will be undermined by future Longwall 12.

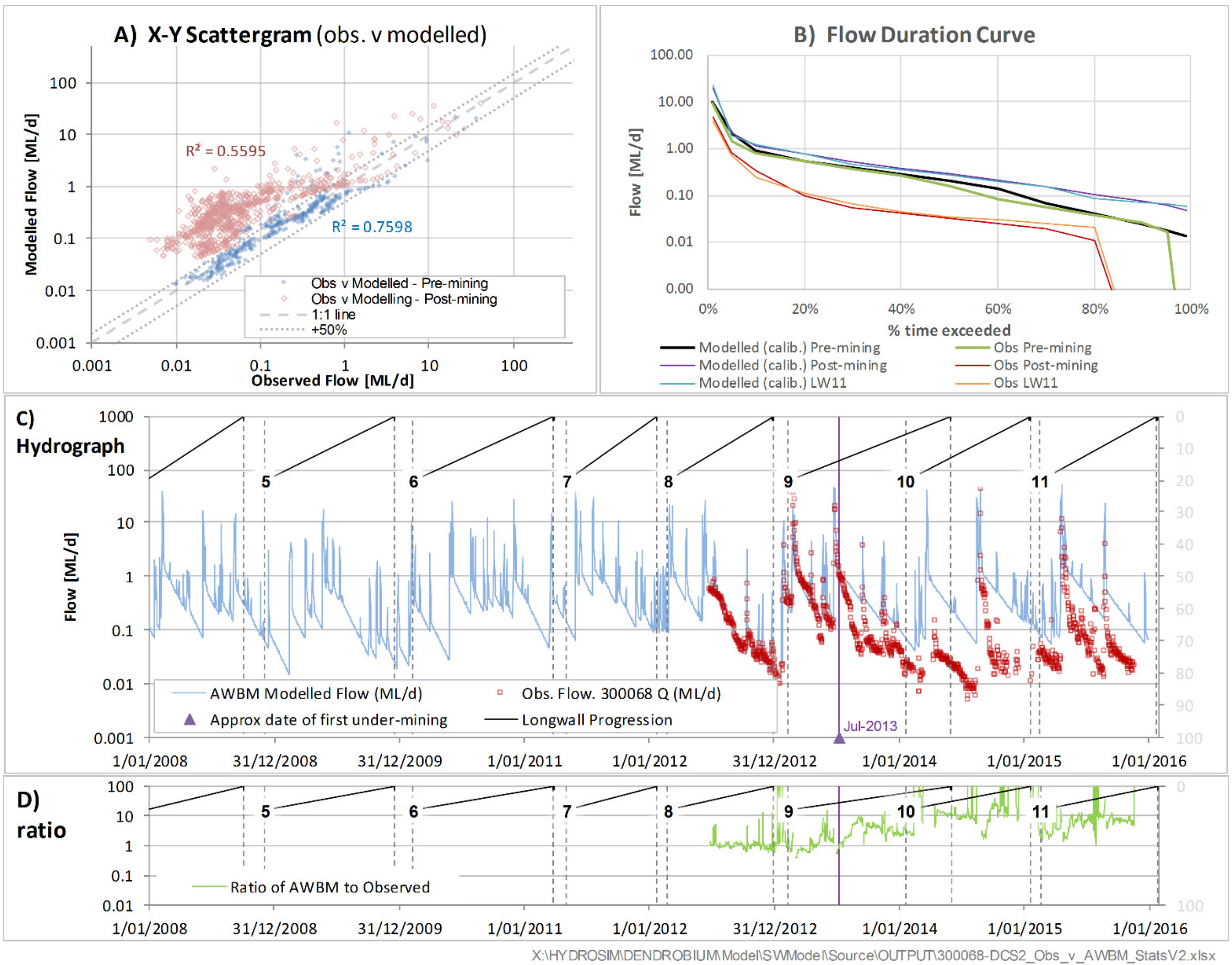


Figure 21 Comparison of Observed and Simulated Flows – DCS2

A	The scattergram shows that during the pre-mining period the model is a good fit to observed data, as shown by the graphical correlation to the 1:1 line and also the R^2. This fit declines significantly in the post-mining period.
B	Confirms the good match between modelled and observed flows for the pre-mining period, and illustrates that the model over-estimates flow for the subsequent post-mining period, including throughout Longwall 11.
C	The hydrograph shows a very good match between observed flows up until July 2013. Some of the peak flows are not well matched (the model tends to overestimate), but the recession is very well matched. After the initial undermining by Longwall 9, the observed hydrograph remains consistently below that predicted by the model, except during the heaviest of rainfall events.
D	The pre-mining ratio of modelled to observed flows shows the ratio hovers at about 1, with deviation during short-term high flow events. The post-mining ratio oscillates around 6-10 through to the end of Longwall 11, with the exception of the period during the second half of Longwall 9 and the early part of Longwall 11 (Jan/Feb-2015), where the average ratio is slightly lower (~3).
Assessment:	Evidence that undermining by Longwall 9 affected the sub-catchment yield, and this continues through Longwalls 10-11; this is supported by the review of observed data (Section 5.1).

Catchment discharge for Longwall 11:	**TARP LEVEL 3**	Water balance [Qsim + ETsim] is 20% below average Pobs.

DCU – Donalds Castle Creek

This catchment incorporates DC13 and DCS2 (**Figure 1**) and was therefore undermined at the commencement of Longwall 9, has been undermined by Longwall 10 and 11, and it will be undermined in the future by Longwall 12. However, the catchment to DCU that lies between those upstream gauges (DC12S1, DCS2) and DCU is not directly undermined.

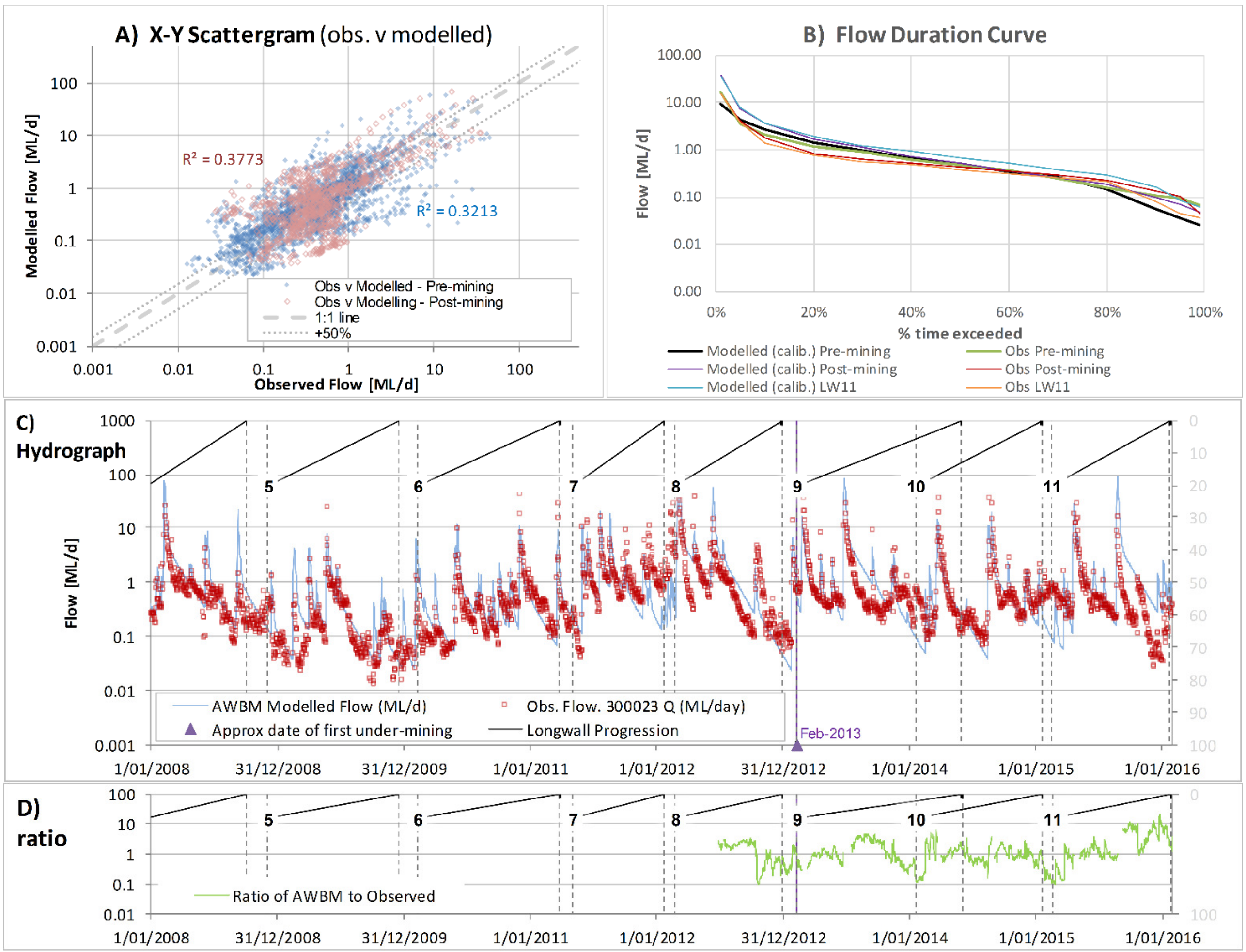


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Figure 22 Comparison of Observed and Simulated Flows – DCU

A	The scattergram shows that during the pre-mining period the model is a reasonable fit to observed data, as shown by the graphical correlation to the 1:1 line and also the R^2. This fit is essentially the same (even marginally better) in the post-mining period.
B	Confirms the good match between modelled and observed flows for the pre-mining period, and illustrates that the model still predicts the range of flows reasonably well for the subsequent post-mining period, including throughout Longwall 11.
C	The hydrograph shows a good match between observed flows up until Feb-2013, and the match is the same after that time. Generally, the flow recessions are well matched, but some are not, e.g. late 2011 – pre-mining and Jan/Feb-2015 - post-mining. The hydrograph suggests that there may be a deviation between modelled and observed flow in late 2015, however this looks somewhat similar to the period mid-2012 – this requires re-examination in the future.
D	The pre-mining ratio of modelled to observed flows shows the ratio hovers at about 1 (i.e. a good match between observed and modelled). The post-mining ratio also oscillates around 1, the exception being at the end of Longwall 11. This catchment was undermined during the first half of Longwall 11.
Assessment:	Despite some suggestion that flow has declined late in LW11, there is no evidence that undermining has reduced sub-catchment yield to a statistically significant degree. Assessment of water quality supports this (Section 4.1).

Catchment discharge for Longwall 11:	**TARP – NOT TRIGGERED**	Water balance [Qsim + ETsim] is within 6% of average Pobs (-2%).

WC15S1 – Wongawilli Creek tributary

This tributary to Wongawilli Creek lies above Longwalls 13-17 of Area 3B, with its confluence with Wongawilli Creek above the eastern end of Longwall 13 (**Figure 1**). As a result, this catchment has not yet been undermined, but will be undermined by future longwalls.

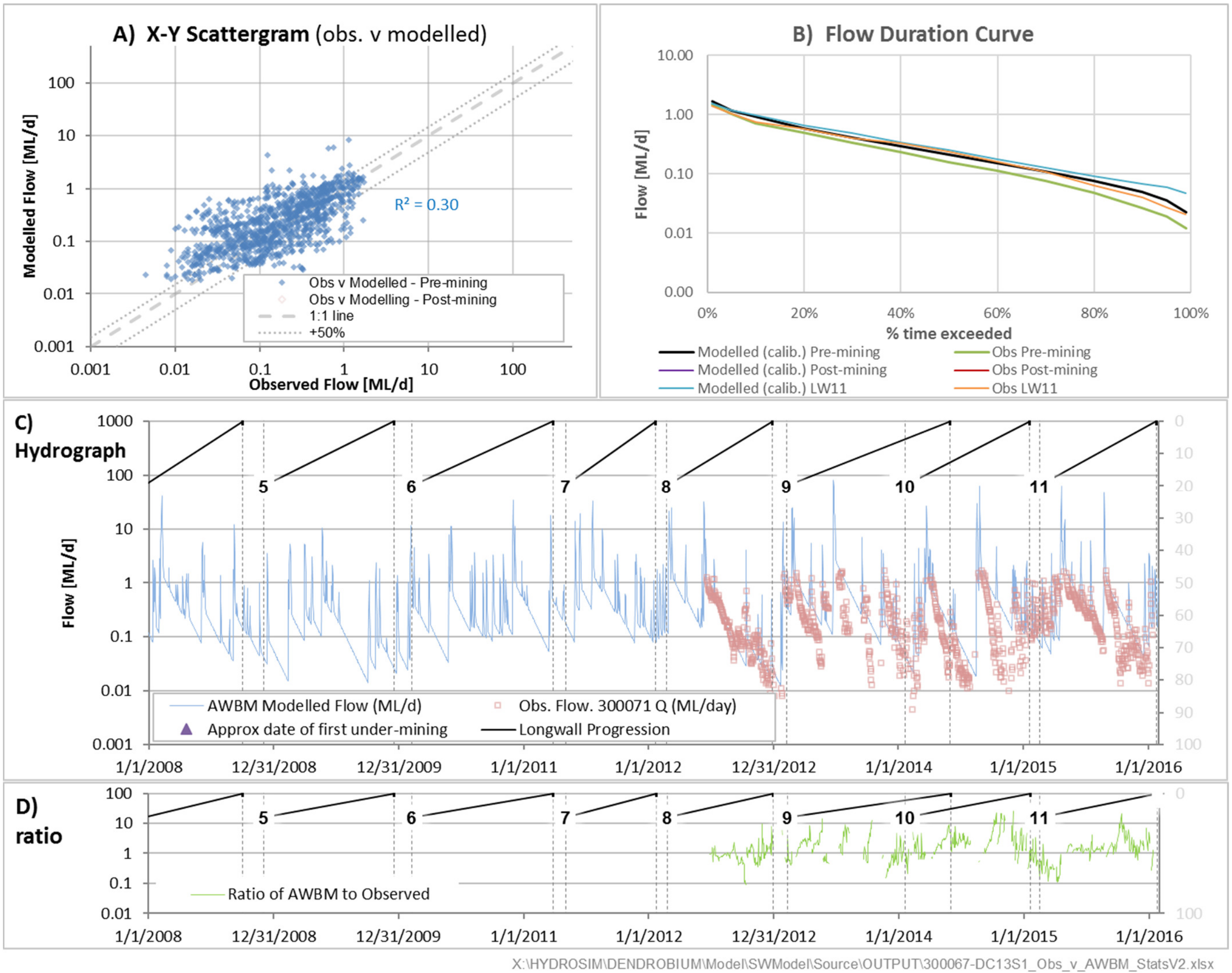

Figure 23 Comparison of Observed and Simulated Flows – WC15S1

A	The scattergram shows that during the pre-mining period the model is a moderate fit to observed data, as shown by the graphical correlation to the 1:1 line and also the R^2. There is no second series as there has been no direct undermining of this catchment.
B	This chart confirms the good match between modelled and observed flows for the pre-mining period, with the main weakness being the lower end of the flow duration curve. The relative difference between observed and modelled for the full sequence and only for the period of Longwall 11 is very similar, suggestive of no mining effect (unsurprising given the lack of direct undermining).
C	The hydrograph shows the fit is somewhat mixed, with periods where there is a very good match to observed flows (e.g. all of Longwall 8, the months immediately preceding Longwall 10, late in Longwall 10 and the first half of Longwall 11, and other periods where the fit is not as good, e.g. mid-way through Longwall 9). However there appears to be no systematic weaknesses in the fit.
D	The pre-mining ratio of modelled to observed flows shows the ratio hovers at about 1, with deviation during some periods, but returning to the baseline value of 1, including during Longwall 11.

Assessment: No evidence that mining has affected flows in this sub-catchment yield, including during Longwall 11.

Catchment discharge for Longwall 11:	**NOT TRIGERRED**	Water balance [Qsim + ETsim] is within 6% of average Pobs.

WC21S1 – Wongawilli Creek tributary

This tributary to Wongawilli Creek lies above Longwalls 9-15 of Area 3B, with its confluence with Wongawilli Creek just north of Longwall 9 (**Figure 1**). This catchment was therefore undermined by the latter stages of Longwall 9, has been undermined by Longwall 10 and 11, and it will be undermined in the future by Longwall 12-15.

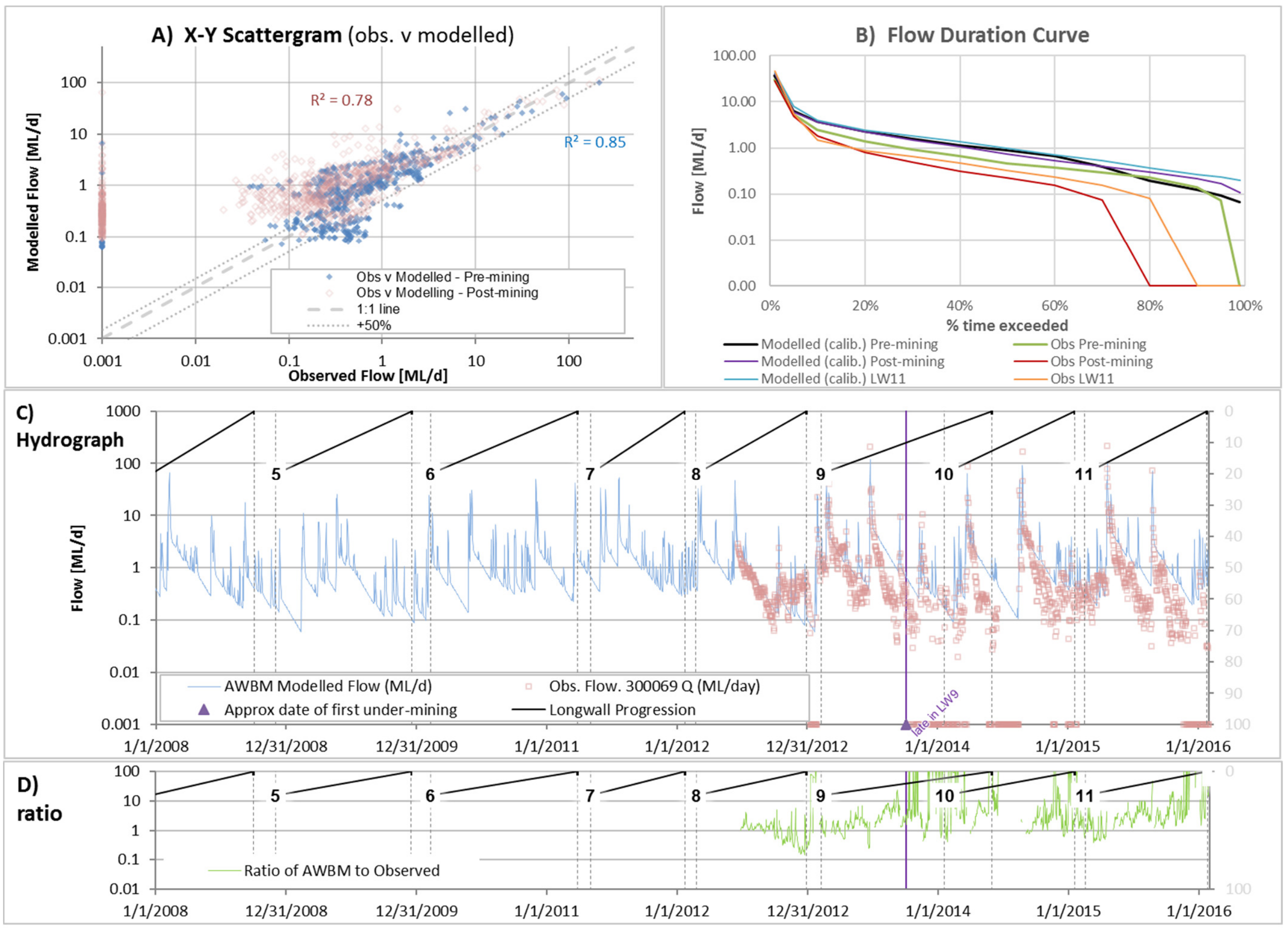

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Figure 24 Comparison of Observed and Simulated Flows – WC21S1

A	The scattergram shows that during the pre-mining period the model is a good fit to observed data, as shown by the graphical correlation to the 1:1 line and also the R^2. This fit declines significantly in the post-mining period.
B	Confirms the good match between modelled and observed flows for the pre-mining period, and illustrates that the observed flows have been below predicted flow for the subsequent post-mining period, including throughout Longwall 11.
C	The hydrograph shows a very good match between observed flows up until August-October 2013. After the initial undermining by Longwall 9, the observed recession limbs are consistently below that predicted by the model.
D	The pre-mining ratio of modelled to observed flows shows the ratio hovers at about 1, with deviation during short-term high flow events. The post-mining ratio oscillates around 2-5 through to the end of Longwall 11, with some periods where the ratio does appear similar to the baseline (1).
Assessment:	The evidence is that recent undermining by Longwall 10 and then Longwall 11 has affected sub-catchment yield. This is supported, to a degree, by the review of observed data (Section 5.1).

Catchment discharge for Longwall 11:	**TARP LEVEL 1**	Water balance [Qsim + ETsim] is 8-10% below average Pobs.

WWL – Wongawilli Creek (lower)

Wongawilli Creek lies between Areas 3A and 3B and the main trunk is not directly undermined, although some tributaries have been or will be undermined by panels in those areas (**Figure 1**).

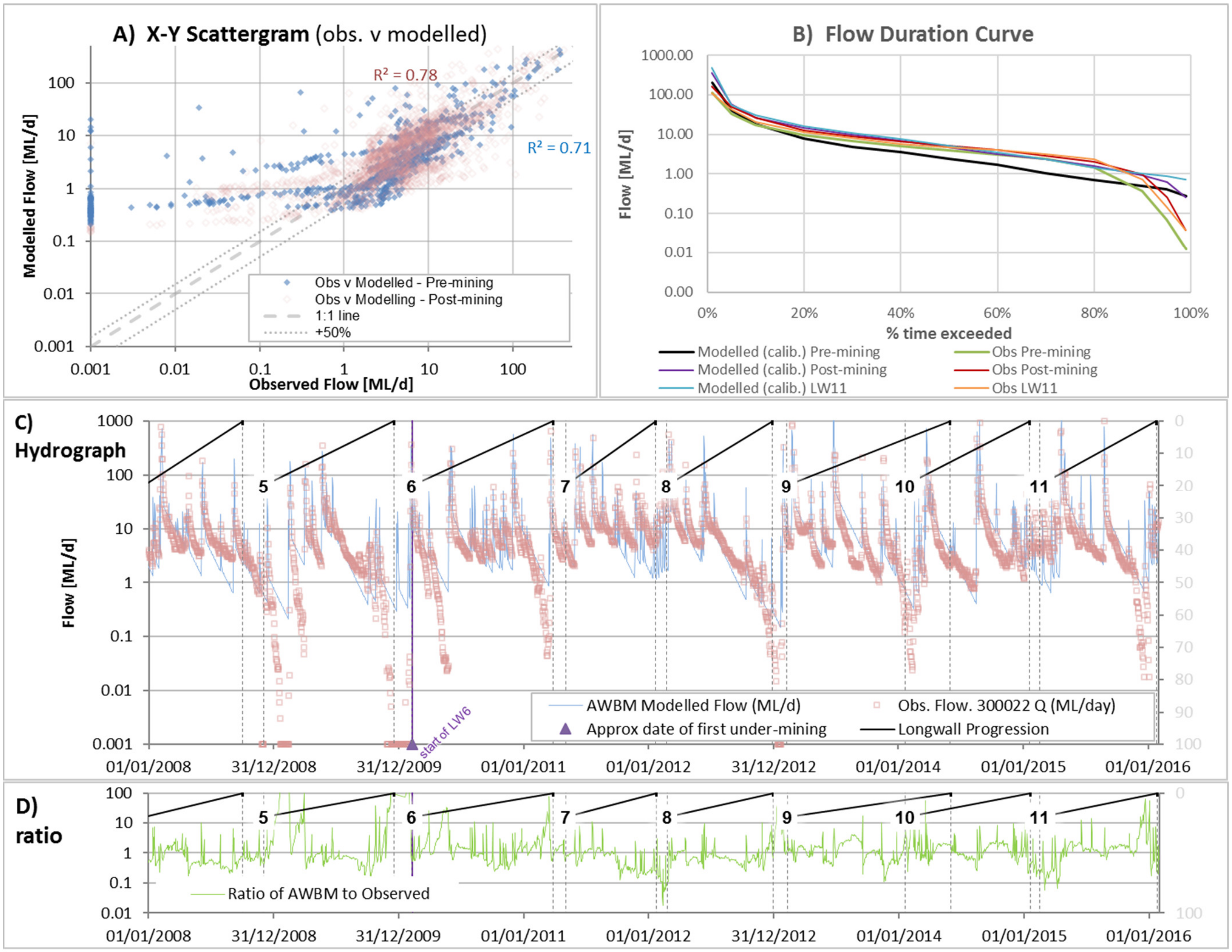

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Figure 25 Comparison of Observed and Simulated Flows – WWL

A This shows that during the pre-mining period the model is a reasonable fit to observed data, with the key weakness being the model's over-estimation of very low flows. This fit is essentially the same (even marginally better) in the post-mining period.

B Confirms the reasonable match between modelled and observed flows for the pre-mining period, and illustrates that the model still predicts the range of flows reasonably well for the subsequent post-mining period, including throughout Longwall 11.

C The hydrograph shows a reasonable match between observed flows up until Feb-2010 (the start of Longwall 6), and the match is the same after that time. Generally, the flow recessions are reasonably matched, but some are over-estimated and some under-estimated in both the pre-mining and post-mining periods. There is no discernible systematic change in behaviour.

D The pre-mining ratio of modelled to observed flows shows the ratio hovers at about 1 (i.e. a good match between observed and modelled). The post-mining ratio also oscillates around 1. The exceptions are the periods of very low (observed) flows, where the model typically over-estimates flows, however this occurs in both pre- and post-mining periods.

Assessment: No evidence that undermining has reduced sub-catchment yield.

Catchment discharge for Longwall 11:	**TARP – NOT TRIGGERED**	Water balance [Qsim + ETsim] is within 6% of average Pobs. (-4%)

LA4_S1 – Lake Avon tributary

This un-named creek lies above the western parts of Longwalls 11-14 in Area 3B, and flows into Lake Avon (**Figure 1**). It has recently been undermined by Longwall 11, and will be undermined by future Longwalls 12-14.

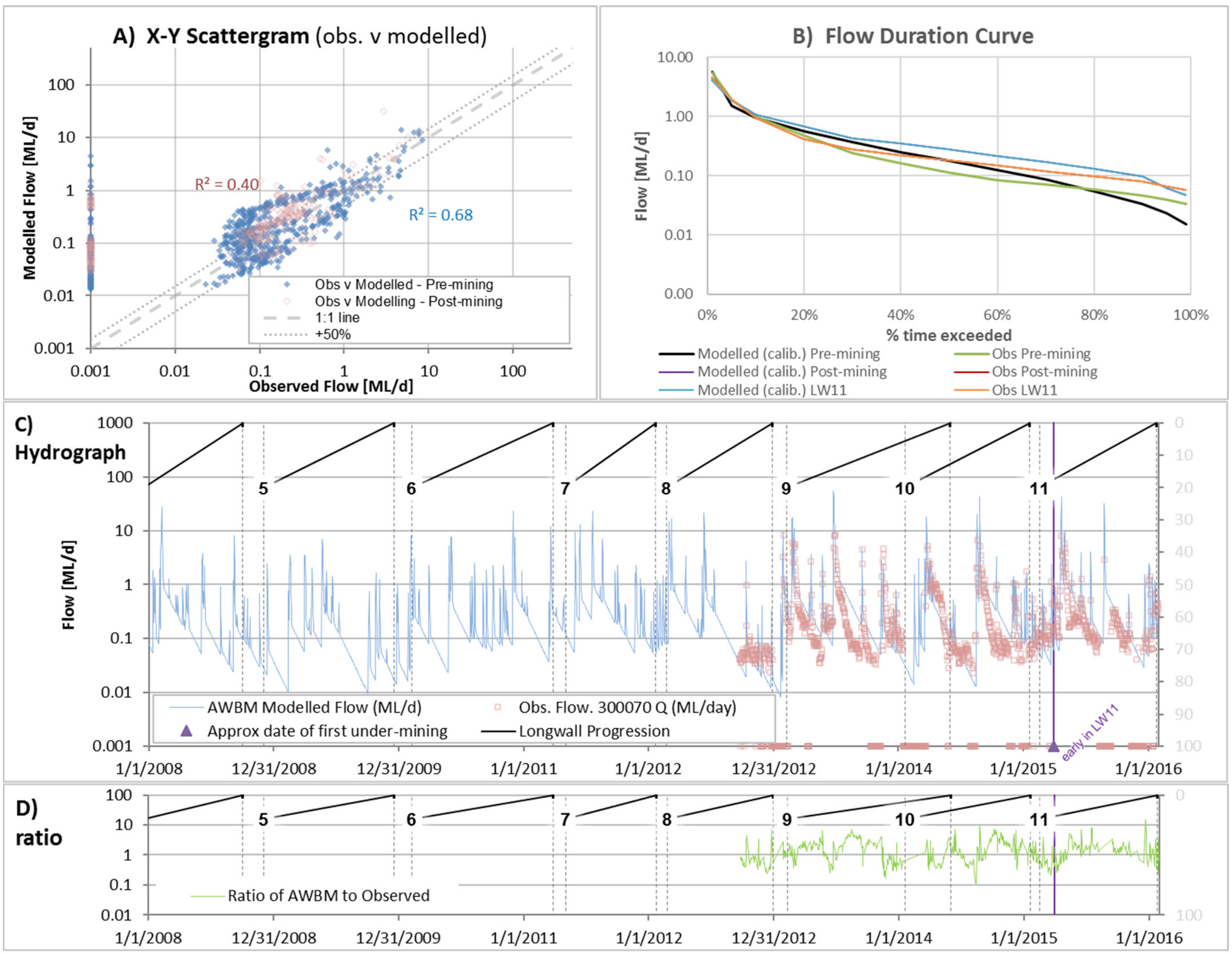

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Figure 26 Comparison of Observed and Simulated Flows – LA4

A	The scattergram shows that during the pre-mining period the model is a reasonable fit to observed data, as shown by the graphical correlation to the 1:1 line and also the R^2. This fit is similar in the post-mining period.
B	Confirms the reasonable match between modelled and observed flows for the pre-mining period, and illustrates that the model still predicts the range of flows reasonably well for the subsequent post-mining period, including throughout Longwall 11.
C	The hydrograph shows a reasonable match between observed flows up until early Longwall 11, and the match is the same after that time. Generally, the flow recessions are well matched, but some are not, e.g. mid-2013 and mid-2014 which are both pre-mining.
D	The pre-mining ratio of modelled to observed flows shows the ratio hovers at about 1 (i.e. a good match between observed and modelled). The post-mining ratio also oscillates around 1.

Assessment: No evidence that undermining has reduced sub-catchment yield to a statistically significant degree.

Catchment discharge for Longwall 11:	**TARP – NOT TRIGGERED**	Water balance [Qsim + ETsim] is within 6% below average Pobs.

6 ASSESSMENT OF SHALLOW GROUNDWATER EFFECTS

Trigger values for subsidence-induced decreases in groundwater levels at surface and near surface monitoring sites at Area 3B swamps have been established within the most recent SIMMCP (South32, 2015). Shallow groundwater level has been identified as an indicator of potential changes in ecosystem functionality of the swamps. TARPS are defined as follows:

Level 1:

- Groundwater level lower than baseline level at any monitoring site within a swamp (in comparison to reference swamps); and/or;
- Rate of groundwater level reduction exceeds rate of groundwater level reduction during baseline period at any monitoring site (measured as average mm/ day during the recession curve).

Level 2:

- Groundwater level lower than baseline level at 50% of monitoring sites (within 400 m of mining) within a swamp (in comparison to reference swamps); and/or
- Rate of groundwater level reduction exceeds rate of groundwater level reduction during baseline period at a 50% of monitoring sites (within 400 m of mining) within the swamp.

Level 3:

- Groundwater level lower than baseline level at >80% of monitoring sites (within 400m of mining) within a swamp (in comparison to reference swamps); and/or
- Rate of groundwater level reduction exceeds rate of groundwater level reduction during baseline period at >80% of monitoring sites (within 400 m of mining) within the swamp.

TARP triggers result in the implementation of the TARP actions for shallow groundwater, in which increased intensity and frequency of vegetation monitoring and/ or further investigations of subsidence impacts on bedrock base and rockbars is to occur.

Groundwater level hydrographs for each shallow piezometer are presented in **Appendix C**. The hydrograph is plotted along with the ground level and the base elevation of piezometer, longwall timing, rainfall trend ("rainfall CRM"), and the dates that longwalls pass or undermine (if relevant) a piezometer. Assessment of mining effects has been based on these hydrographs.

A summary of the hydrograph responses at Area 3B swamps can be seen in **Table 5** for Impact Sites and **Table 6** for Reference Sites. In accordance with the definition of the TARPs, the sites included for the assessment against the triggers are only those within 400 m of mining *and* within the mapped swamp areas (current version of the site-scale mapping is Dendrobium_SwampV6 [mapping by Biosis, 2015] - **Figure 3**).

Table 5 Summary of shallow groundwater level TARP status at *Impact Sites*

SWAMP	NUMBER OF PIEZO-METERS OBSERVED	RELEVANT LONGWALLS	PIEZOMETERS WITH AN OBSERVED RESPONSE TO MINING			OBSERVED BEHAVIOUR	COMMENT	TARP LEVEL
			YES	POSSIBLE	NO			
01a^	8	LW9, LW10	01, 04, 04i, 04ii, 04iii, 04iv, 04v		02	Groundwater levels lower than baseline and recession rate greater than baseline at greater than 50% to 90% of monitoring sites	Limited baseline data for five piezometers.	Level 3^
01b^	5	LW9	02, 02iii	02ii, 02iv	01	Groundwater levels lower than baseline and recession rate greater than baseline at greater than 50% of monitoring sites.	Limited baseline data for five piezometers	Level 2^
03	1	Pillar 11/12	01			Probable increase in recession rate from baseline, plus possible lack of response to rainfall in Jan 2016.	Further response may be observed with mining LW12	Level 3
05	8	LW9, LW10, LW11	01, 02, 03, 03i, 03ii, 03iii, 04,		05	Groundwater levels lower than baseline and recession rate greater than baseline at >80% of monitoring sites	Limited baseline data for one piezometer, insufficient recent data for two piezometers	Level 3
08	4	LW9, LW10 LW11	01, 04		02	Groundwater levels lower than baseline and recession rate greater than baseline at a number of piezometers, however these piezometers are not within swamp boundary.	Limited baseline data for one piezometer, insufficient recent data for one piezometer	Not assessed.
10	1	LW12			01	n/a	Yet to be undermined	n/a
13	1	LW14			01	n/a	Yet to be undermined	n/a
14	2	LW15, LW16			01, 02	n/a	Yet to be undermined. (no data since Sept 2015*)	n/a
23	2	LW15, LW16			01, 02	n/a	Yet to be undermined. (no data since August 2015*)	n/a

Note: " i " in site name (e.g. 04i) indicates installation during Longwall 9 extraction. These piezometers are of limited use diagnostically due to a lack of observations establishing baseline conditions (observations prior to mining)

* at these swamps which are located away from active or recent mining areas the data has been logged (recorded) at the piezometer, but not collected since that time.

^ the *Longwall 11 End of Panel Landscape Assessment* (South32, 2016) assessed Swamps 01a+0b1 as a single entity, in which case the TARP Level would be L2. Either approach could be considered appropriate.

Table 6 Summary of shallow groundwater level TARP status at *Reference Sites*.

SWAMP	NUMBER OF PIEZO-METERS	UNDERMINED BY LONGWALLS	PIEZOMETERS WITH AN OBSERVED RESPONSE TO MINING?			OBSERVED IMPACTS	COMMENT	TARP LEVEL
			YES	POSSIBLE	NO			
02	1	900 m from LW9			01	n/a	900 m from LW9	Not Triggered
07	2	1.2 km from LW6			01, 0	n/a	1.2 km from LW6	Not Triggered
15a	3	LW8, LW19		18	06, 07	Possible groundwater level impact. Lack of baseline data before LW8 extraction.	Limited baseline data for piezometer 18, not to be directly undermined	Not Triggered
22	2	Elouera Colliery			01, 02	n/a	Limited baseline data	Not Triggered
25	1	1.4 km from LW5			01	n/a	1.4 km from LW5	Not Triggered
33	2	1 km from LW16			01, 03	n/a	1 km from LW16	Not Triggered
84	1	500 m from LW5			01	n/a	500 m from LW5	Not Triggered
85	2	900 m from LW9			01, 02	n/a	900 m from LW9	Not Triggered
86	2	3 km from LW9			01, 02	n/a	3 km from LW9	Not Triggered
87	2	Avon Colliery			01, 02	n/a	Limited baseline data	Not Triggered
88	2	Huntley Colliery			2	n/a	Limited baseline data	Not Triggered

7 CONCLUSIONS

7.1 WATER QUALITY

Donalds Castle Creek

There was a minor change to Dissolved Oxygen (DO) at DCS2 during Longwall 11, triggering a Level 1 TARP.

No other water quality TARPs were triggered in the Donalds Castle Creek catchment during this assessment period.

Wongawilli Creek

DO fell below the TARP trigger level on non-consecutive occasions at WC15S1 during Longwall 11, triggering a Level 2 TARP.

No other water quality TARPs were triggered in the Wongawilli Creek catchment during this assessment period, although some increases in pH, Fe and Mn were observed at WC21_Pool5 during Longwalls 10 and 11. The effects observed at WC21_Pool 5 were not evident 500 m downstream in Wongawilli Creek at site WC_S1 which is located just below the confluence of WC21 and Wongawilli Creek.

Lake Avon tributaries

No water quality TARPs were triggered in the tributaries to Lake Avon during this assessment period.

7.2 FLOW AND CATCHMENT 'YIELD'

The modelling assessment indicates that headwater catchments to DC13S1, DCS2, WC21S1 are affected by under-mining. Effects are not clearly observed in the downstream catchments to Donalds Castle Upper (DCU) and Wongawilli Creek Lower (WWL); this suggests that some or all flow lost in the headwater catchments is returned downgradient, but is not conclusive, as evapotranspiration (ET) might account for some fraction of that.

Modelling suggests that flows at the high range of flows in those headwater catchments are less affected than the lower, recession-limb flows.

An assessment of 'yield', which is defined here as ET_{sim} + Q_{sim}, has been carried out in accordance with the TARPs and is summarised below.

Donalds Castle Creek

Based on both a modelling assessment and a review of observed data it is found that there is a loss of sub-catchment yield in the headwater catchments of Donalds Castle Creek (to DC13S1 and DCS2) through the period of most of Longwall 9, through Longwall 10 and Longwall 11. DCS2 is at TARP Level 3, and DC13S1 is at TARP Level 2.

There is no observable decline in catchment flow + ET at the downstream gauging station DCU (i.e. it remains below TARP Level 1).

Wongawilli Creek

Based on both a modelling assessment and a review of observed data there is a loss of sub-catchment yield in the main tributary catchments of Wongawilli Creek that overlie Area 3B (the catchment of WC21) through the period of most of Longwall 9, through Longwall 10 and Longwall 11. WC15 is yet to be undermined.

There is no observable significant decline in sub-catchment yield through the next downstream gauging station WWL (i.e. below TARP Level 1).

Lake Avon tributaries

Based on both a modelling assessment and a review of observed data there is no discernible loss of sub-catchment yield in the LA4 tributary of Lake Avon.

7.3 SWAMPS

The *Dendrobium Area 3B Swamp Impact, Monitoring, Management and Contingency Plan* (South32, 2015b) indicated that Swamps 01a, 01b, 03, 04, 05, 08, 10, 11, 13, 14, 23, 35a and 35b might be affected by mine subsidence due to mining in Area 3B. The assessment of shallow groundwater levels indicates that TARPs have been triggered at the following swamps, including two which are now at Level 3:

- Swamp 01a Level 3.
- Swamp 01b Level 2.
  - Swamps 01a+01b would be Level 2 if considered one entity.
- Swamp 03 Level 3 (although not conclusive at this stage).
- Swamp 05 Level 3.
- Swamp 08 Level 2.

Most of these had been triggered before based on the assessment in the previous Longwall 10 End of Panel report (Ecoengineers, 2015).

8 RECOMMENDATIONS

The AWBM rainfall-runoff model has been adopted for this assessment. This rainfall-runoff model is an industry-standard, and is considered to have performed reasonably well here. However, a model that takes more account of the potential for evaporation from shallow water tables, not just the soil zone, might be better at simulating the recession into extremely low flows at some sites (e.g. WWL on Wongawilli Creek). This approach should be investigated to determine if it would allow for a more consistent comparison of modelled versus observed flows between pre- and post-mining periods.

9 REFERENCES

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APPENDIX A

Water Quality Plots (Key Parameters) for all Monitoring Sites

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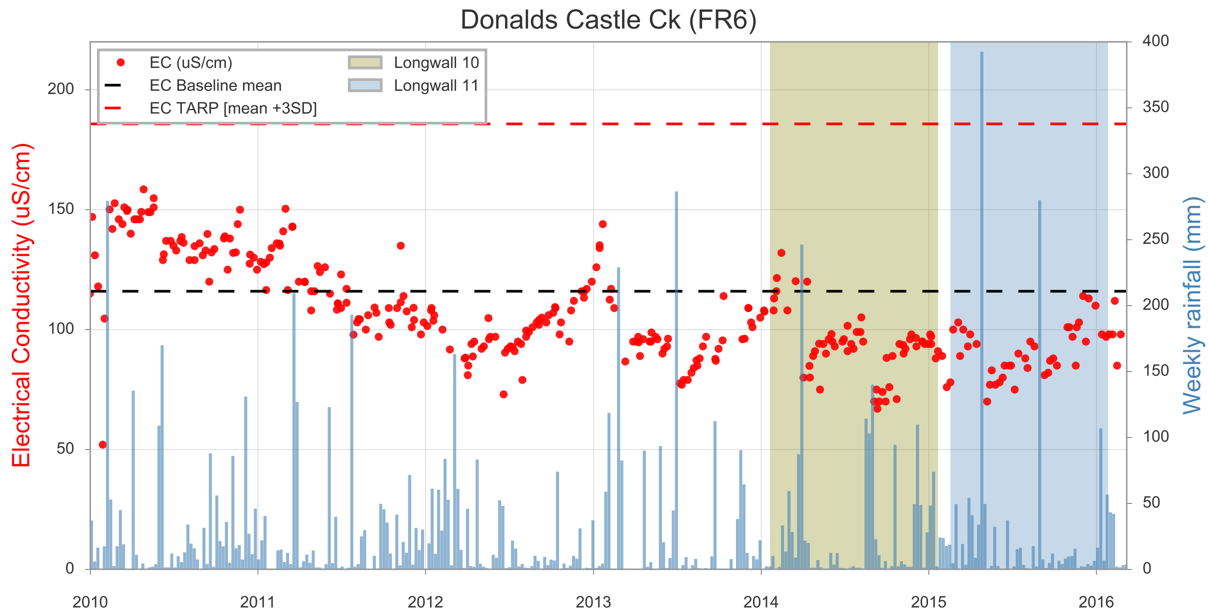
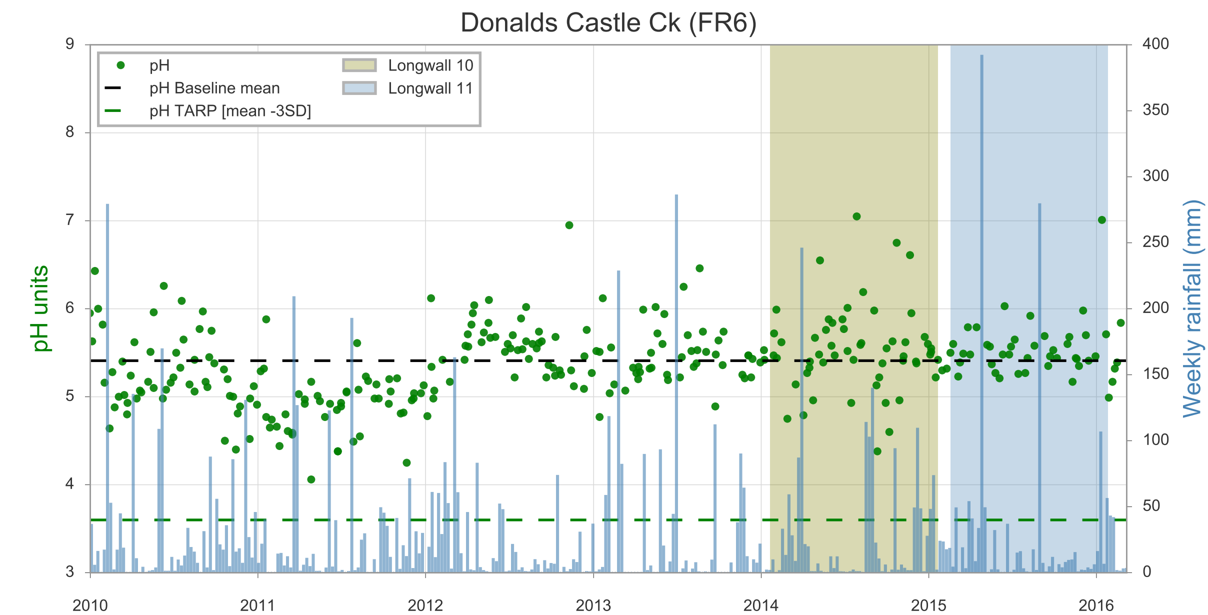
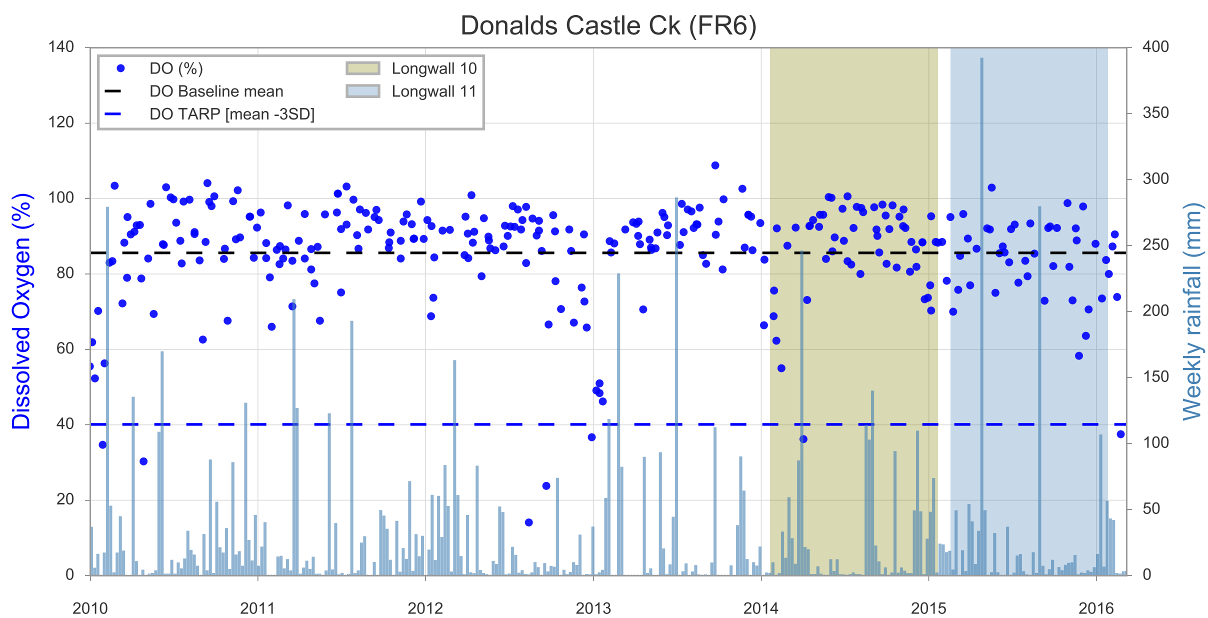


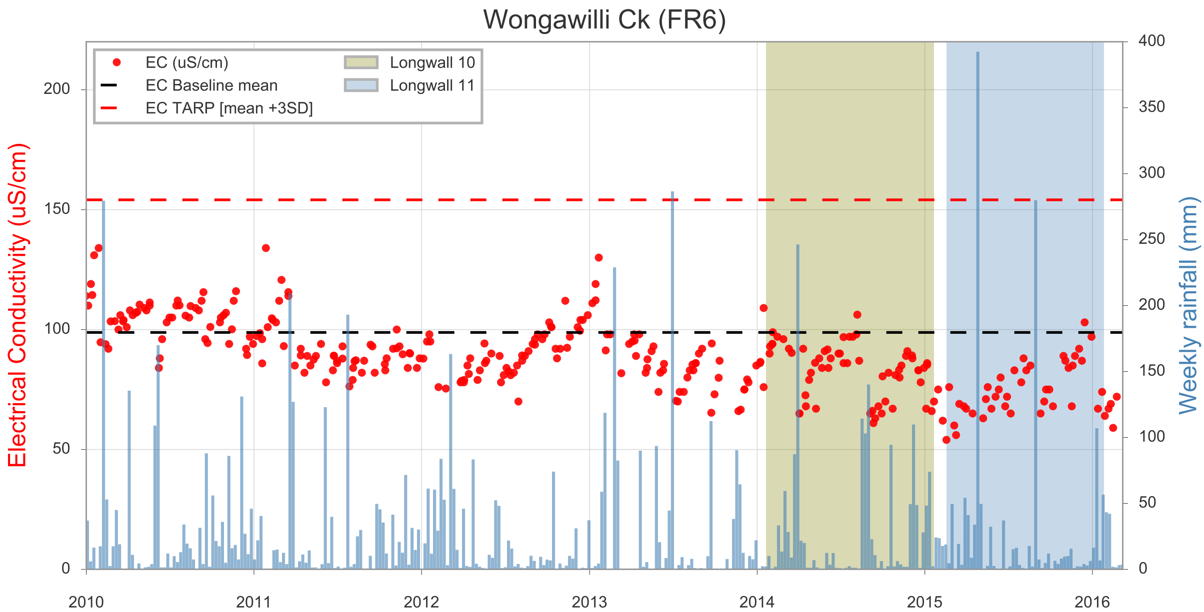
Donalds Castle Ck (FR6)
EC (uS/cm)
EC Baseline mean
EC TARP [mean +3SD]
Longwall 10
Longwall 11
Electrical Conductivity (uS/cm)
Weekly rainfall (mm)
0
50
100
150
200
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016



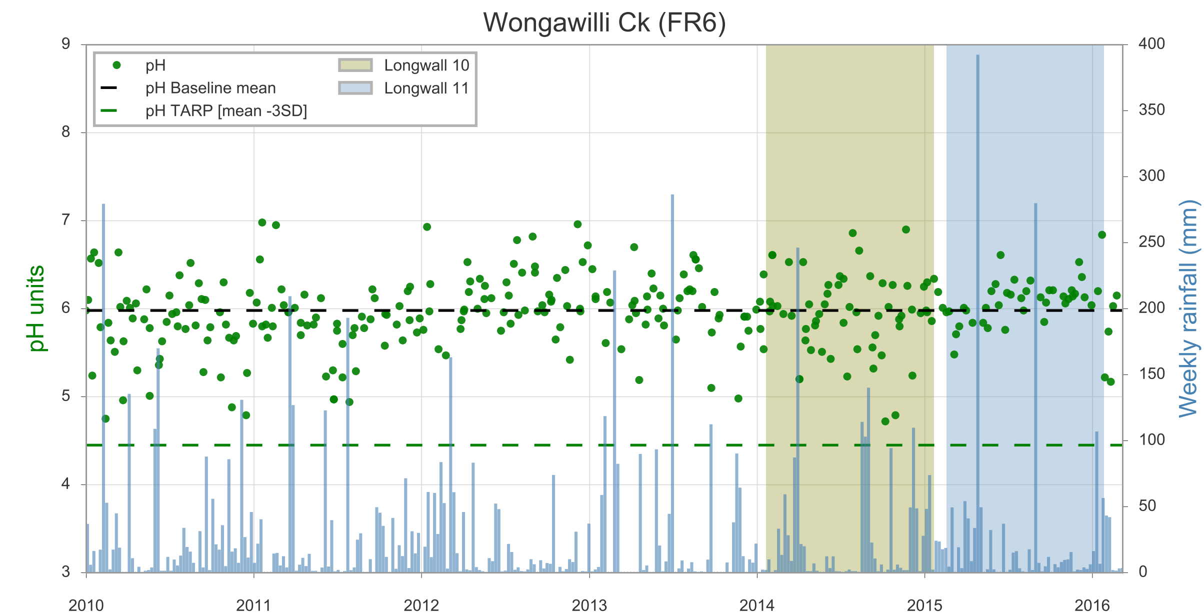
Donalds Castle Ck (FR6)
pH
pH Baseline mean
pH TARP [mean -3SD]
Longwall 10
Longwall 11
pH units
Weekly rainfall (mm)
3
4
5
6
7
8
9
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016



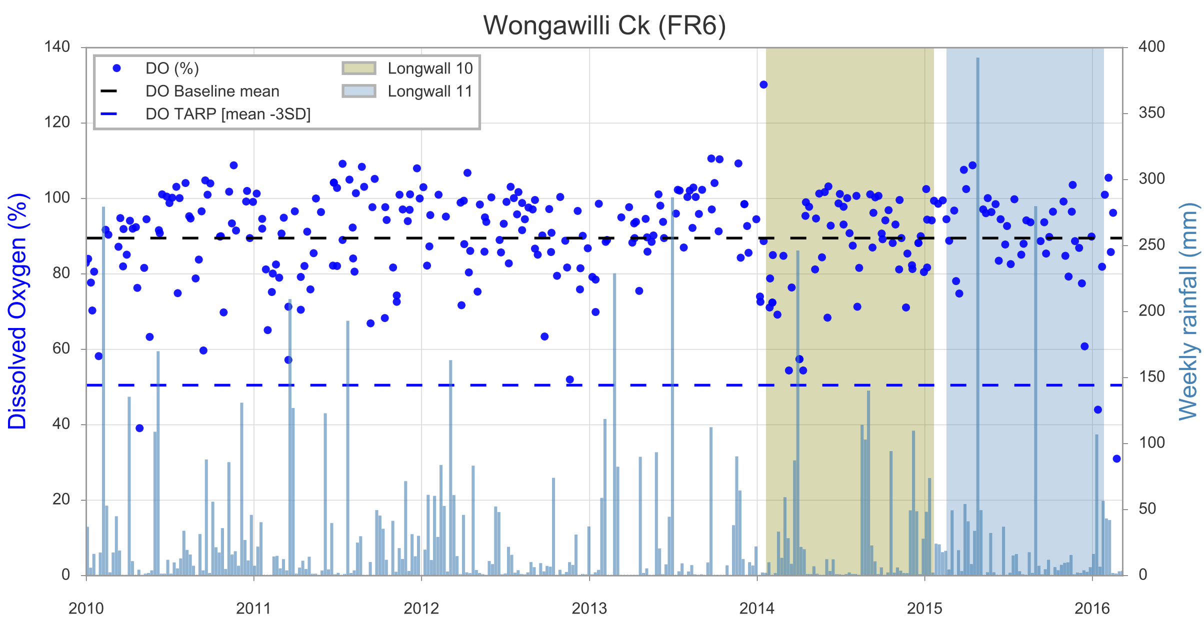
Donalds Castle Ck (FR6)
DO (%)
DO Baseline mean
DO TARP [mean -3SD]
Longwall 10
Longwall 11
Dissolved Oxygen (%)
Weekly rainfall (mm)
0
20
40
60
80
100
120
140
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016



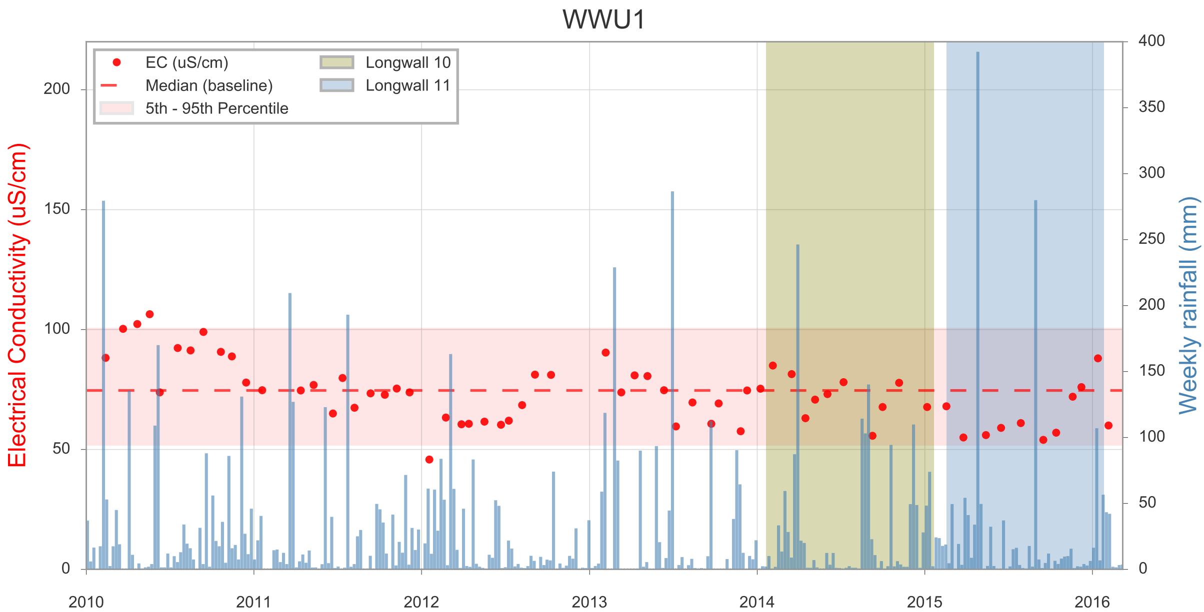
Wongawilli Ck (FR6)
EC (uS/cm)
EC Baseline mean
EC TARP [mean +3SD]
Longwall 10
Longwall 11
Electrical Conductivity (uS/cm)
Weekly rainfall (mm)
0
50
100
150
200
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016

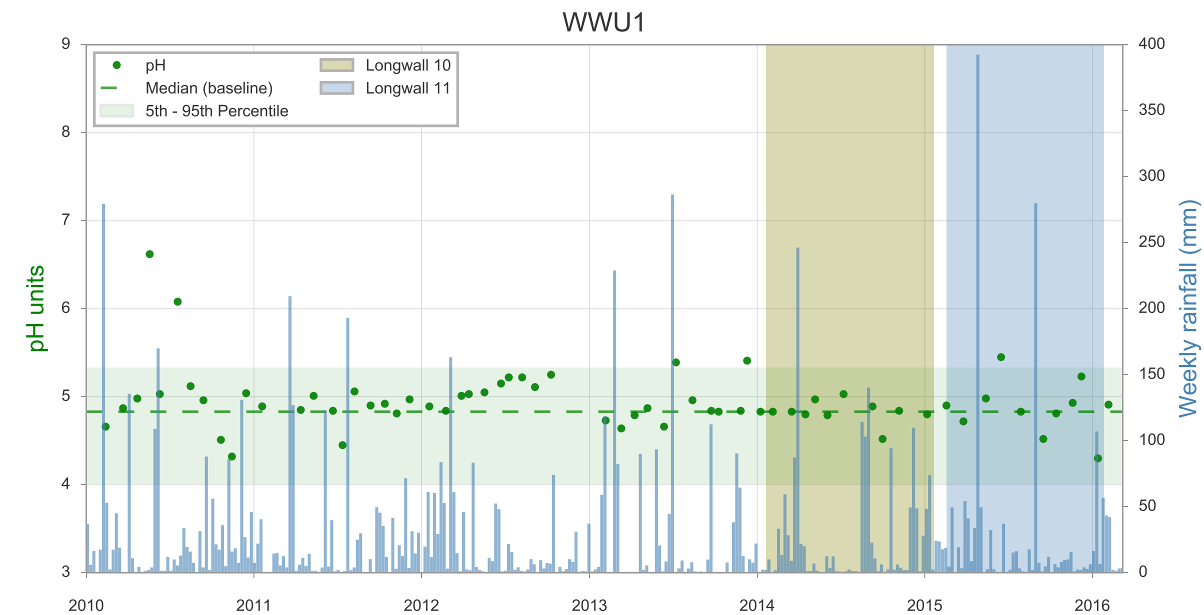


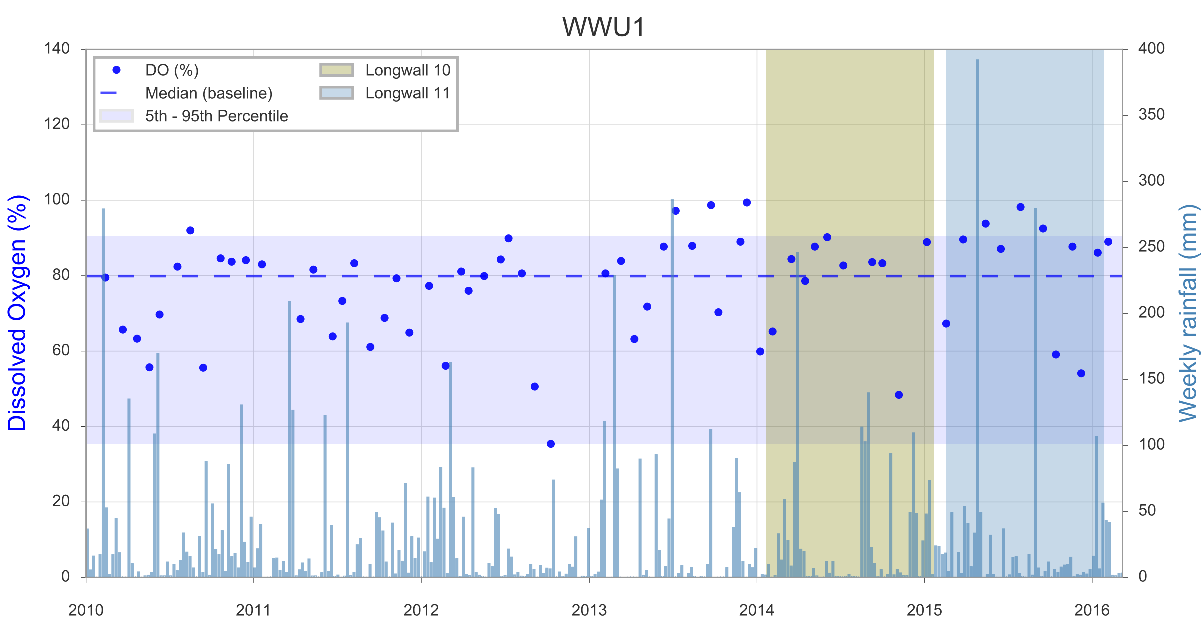
Wongawilli Ck (FR6)
pH
pH Baseline mean
pH TARP [mean -3SD]
Longwall 10
Longwall 11
pH units
Weekly rainfall (mm)
3
4
5
6
7
8
9
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016



Wongawilli Ck (FR6)
DO (%)
DO Baseline mean
DO TARP [mean -3SD]
Longwall 10
Longwall 11
Dissolved Oxygen (%)
Weekly rainfall (mm)
0
20
40
60
80
100
120
140
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016


WWU1
EC (uS/cm)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Electrical Conductivity (uS/cm)
Weekly rainfall (mm)
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016


WWU1
pH
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
pH units
Weekly rainfall (mm)
3
4
5
6
7
8
9
2010
2011
2012
2013
2014
2015
2016


WWU1
DO (%)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Dissolved Oxygen (%)
Weekly rainfall (mm)
0
20
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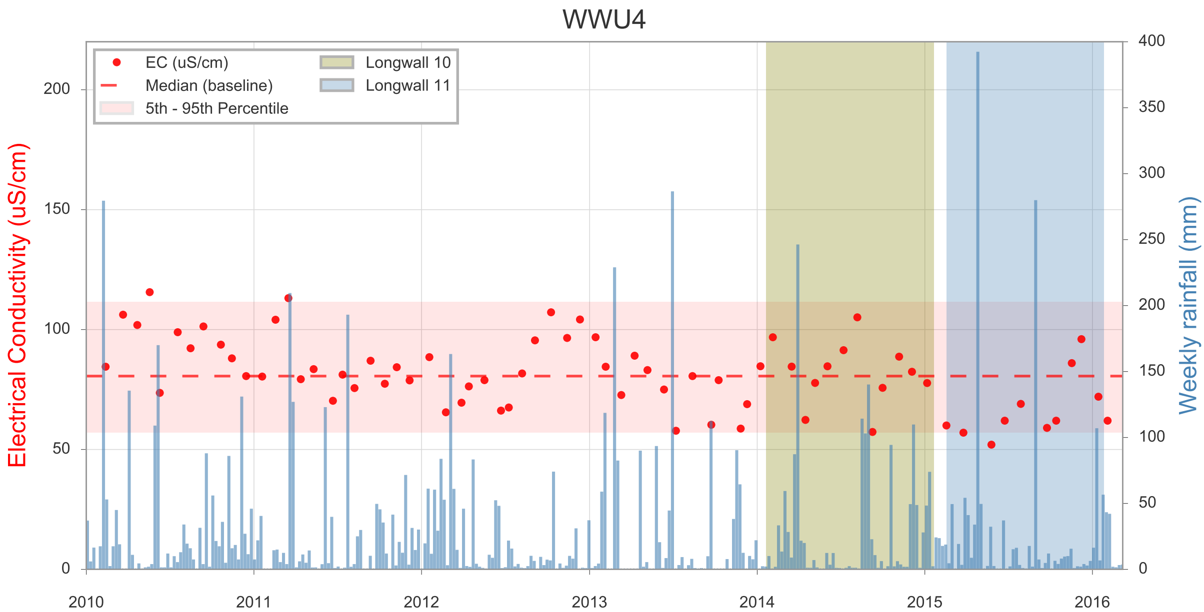
60
80
100
120
140
2010
2011
2012
2013
2014
2015
2016


WWU4
EC (uS/cm)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Electrical Conductivity (uS/cm)
Weekly rainfall (mm)
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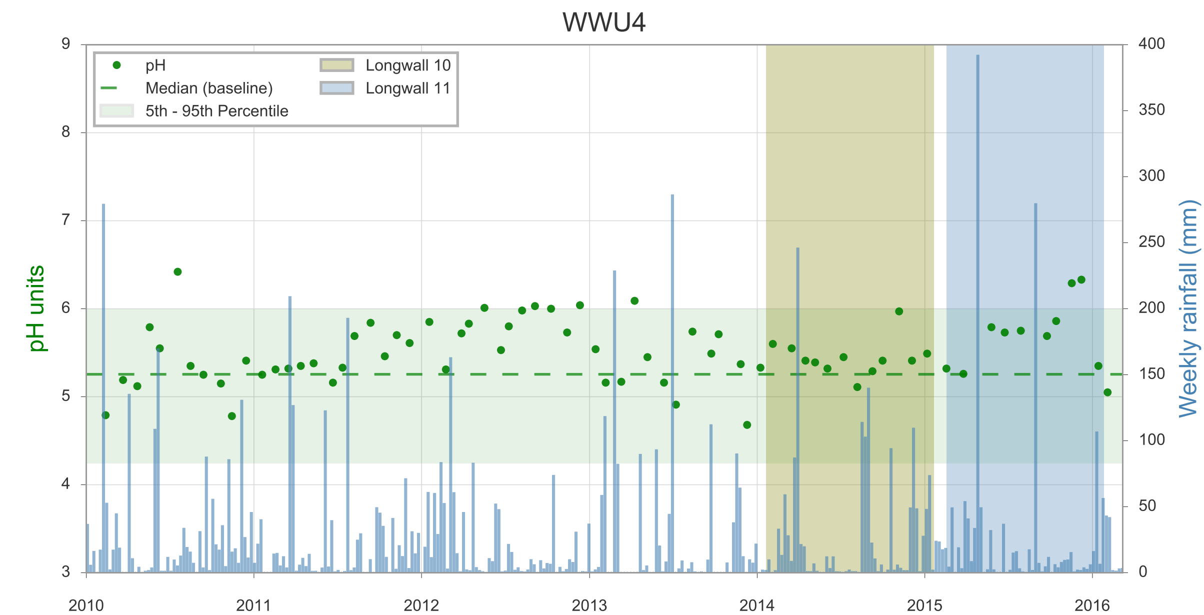
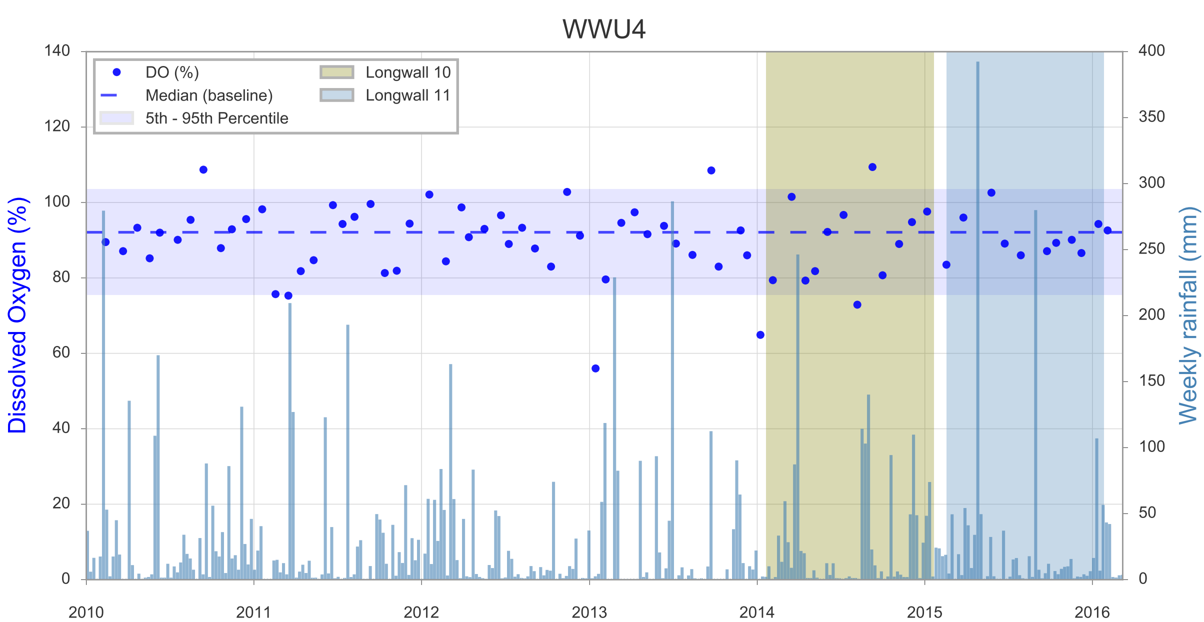
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016


WWU4
pH
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
pH units
Weekly rainfall (mm)
3
4
5
6
7
8
9
2010
2011
2012
2013
2014
2015
2016


WWU4
DO (%)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Dissolved Oxygen (%)
Weekly rainfall (mm)
0
20
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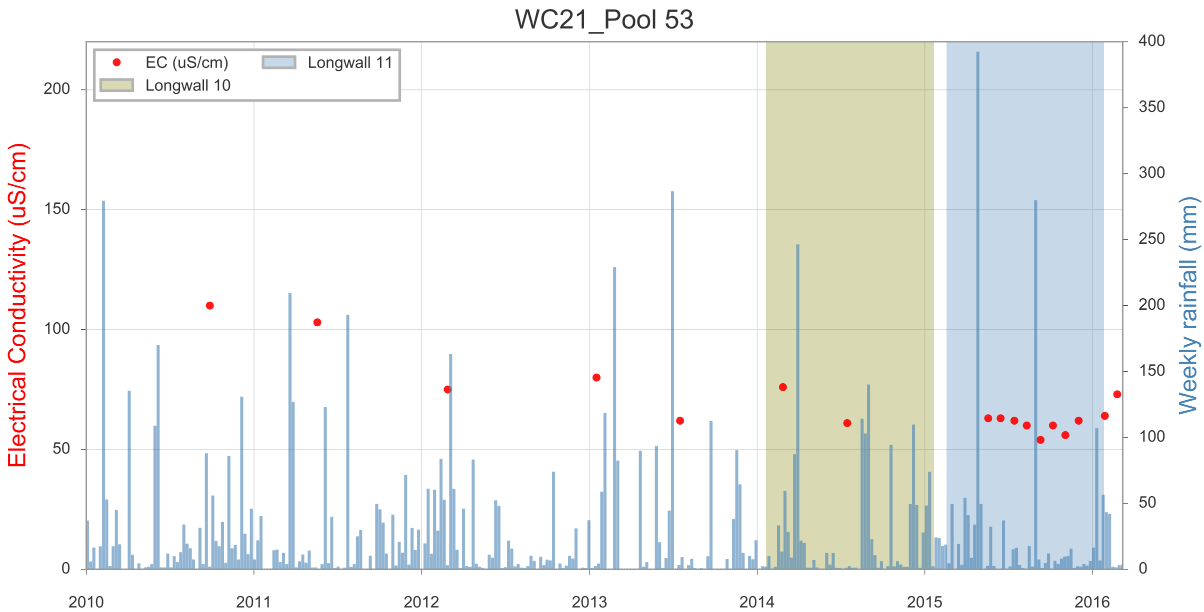
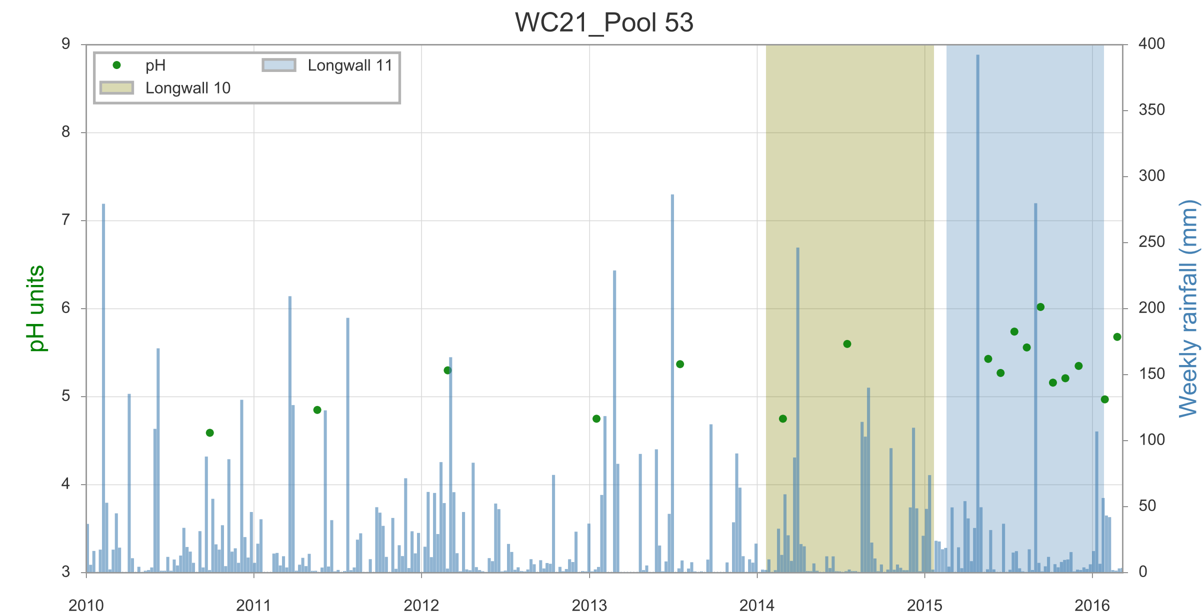
60
80
100
120
140
2010
2011
2012
2013
2014
2015
2016


WC21_Pool 53
EC (uS/cm)
Longwall 10
Longwall 11
Electrical Conductivity (uS/cm)
Weekly rainfall (mm)
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016


WC21_Pool 53
pH
Longwall 10
Longwall 11
pH units
Weekly rainfall (mm)
3
4
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7
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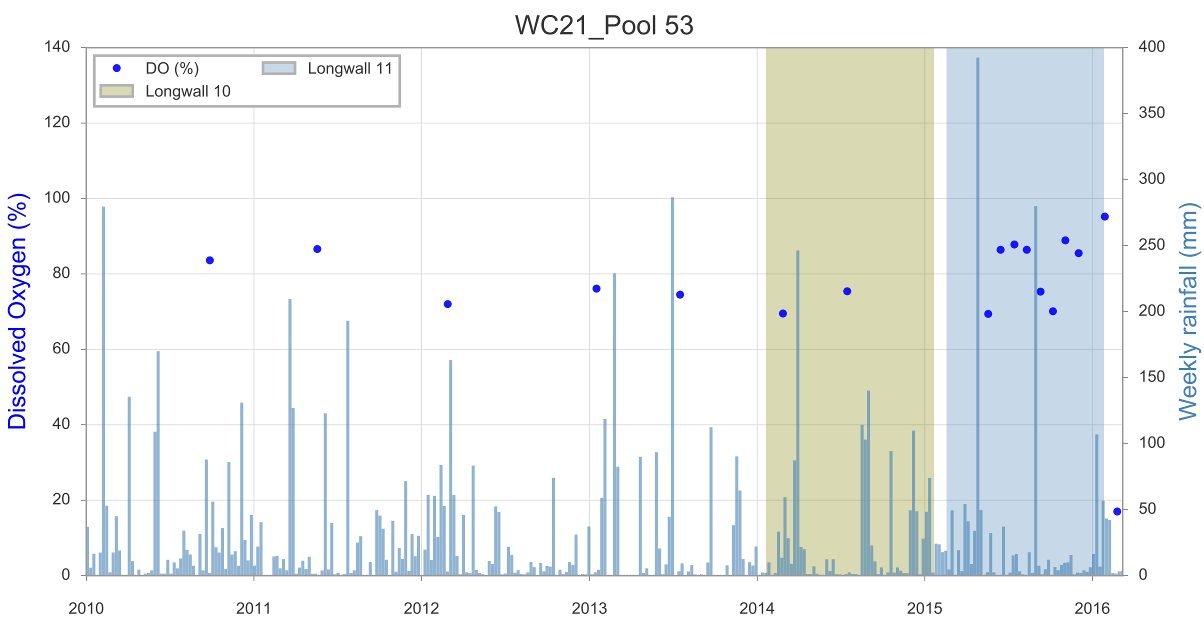
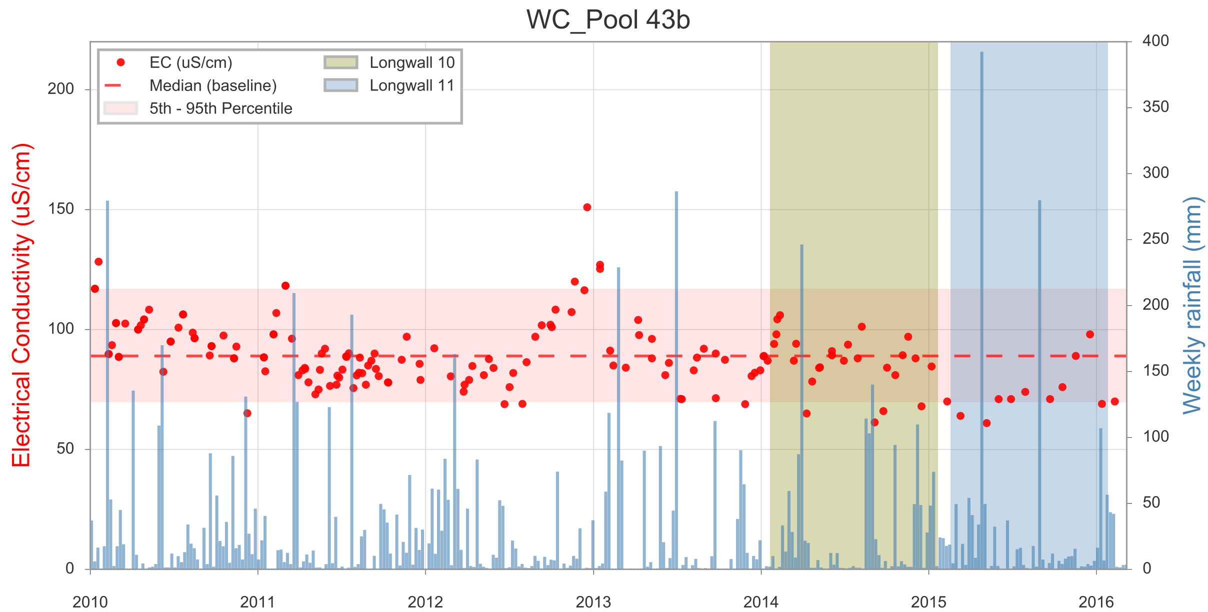
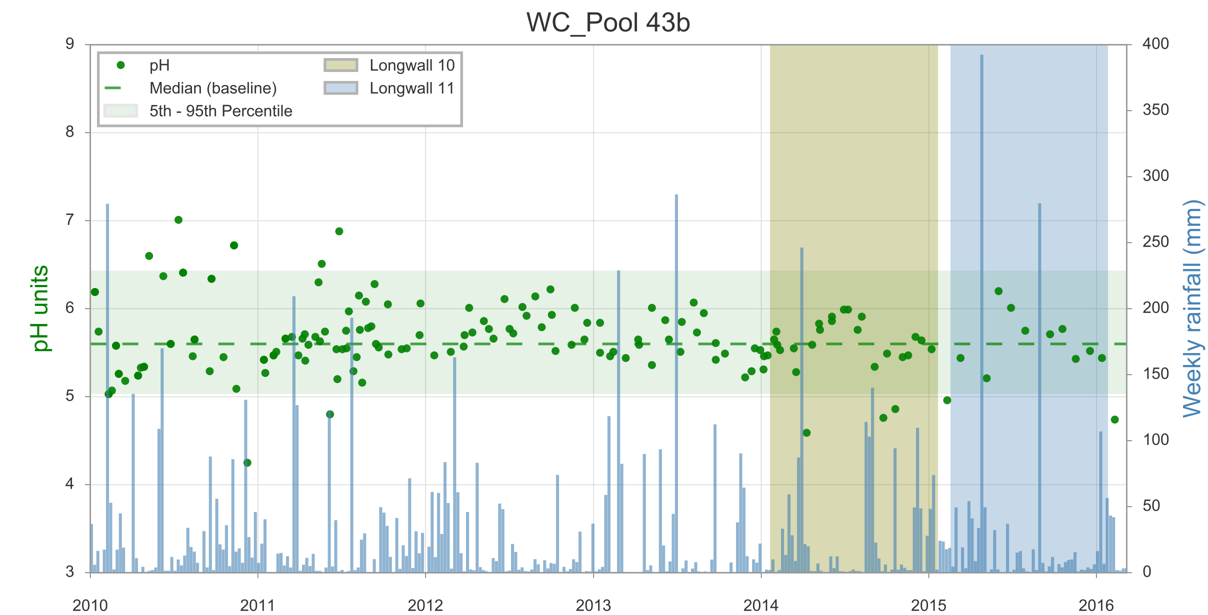
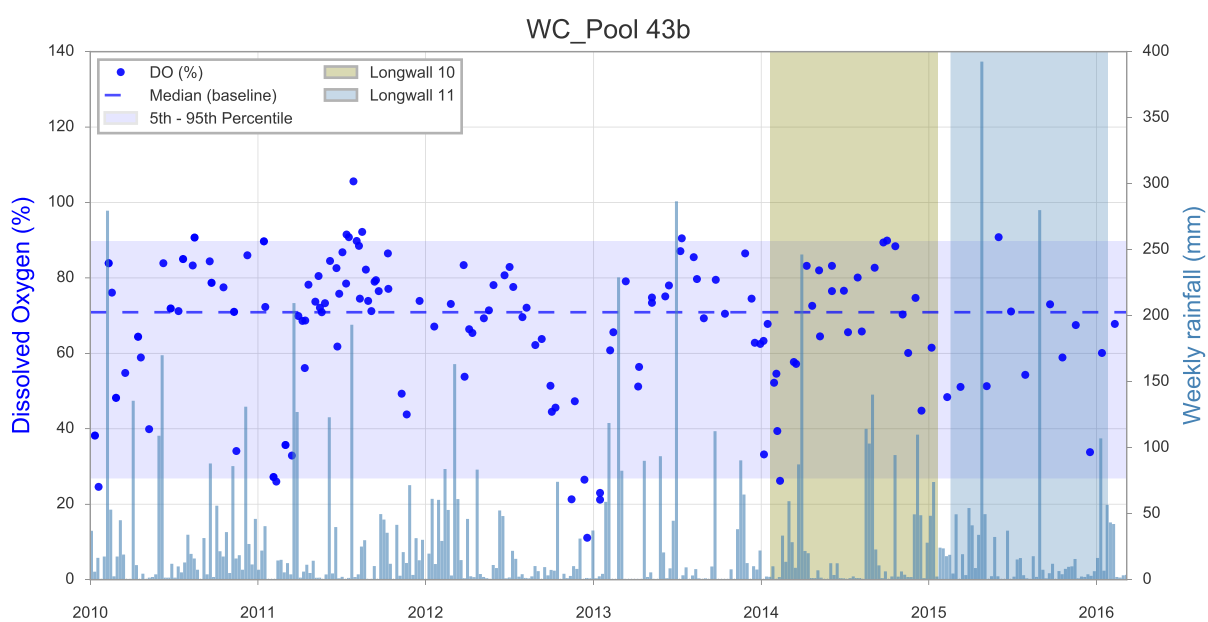
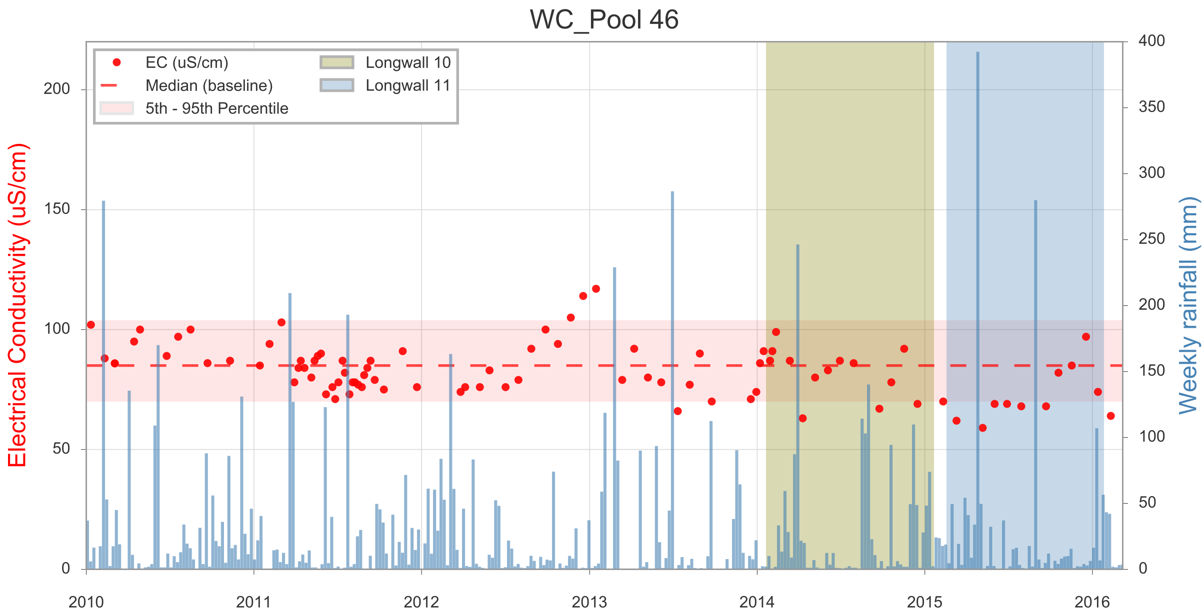
9
2010
2011
2012
2013
2014
2015
2016


WC21_Pool 53
DO (%)
Longwall 10
Longwall 11
Dissolved Oxygen (%)
Weekly rainfall (mm)
0
20
40
60
80
100
120
140
2010
2011
2012
2013
2014
2015
2016

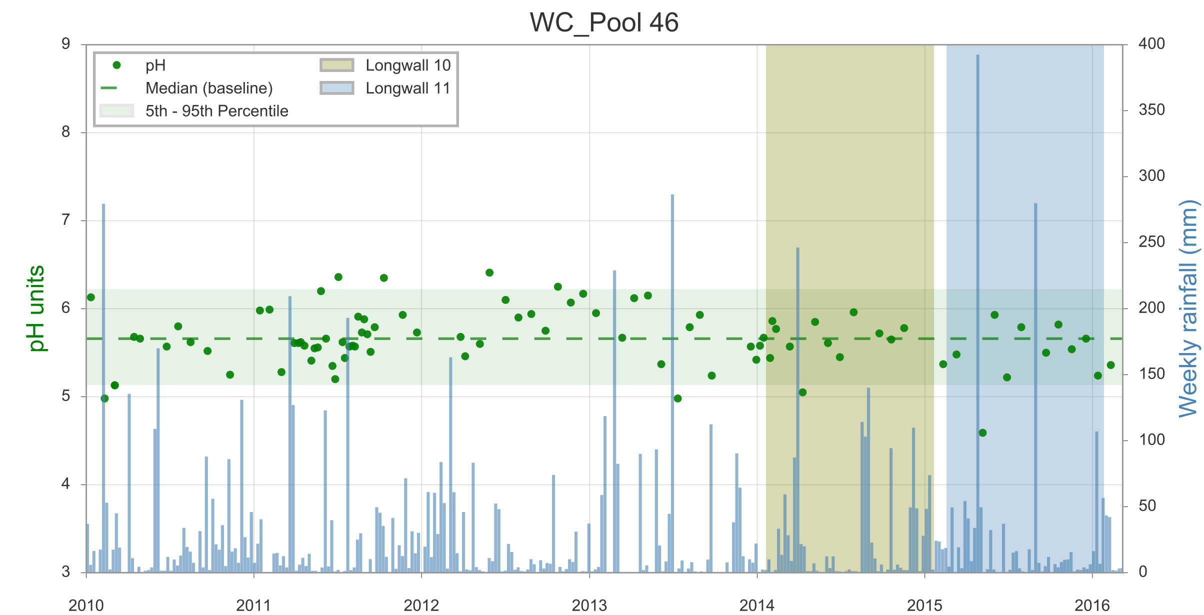

WC_Pool 43b
EC (uS/cm)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Electrical Conductivity (uS/cm)
Weekly rainfall (mm)
2010
2011
2012
2013
2014
2015
2016


WC_Pool 43b
pH
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
pH units
Weekly rainfall (mm)
2010
2011
2012
2013
2014
2015
2016

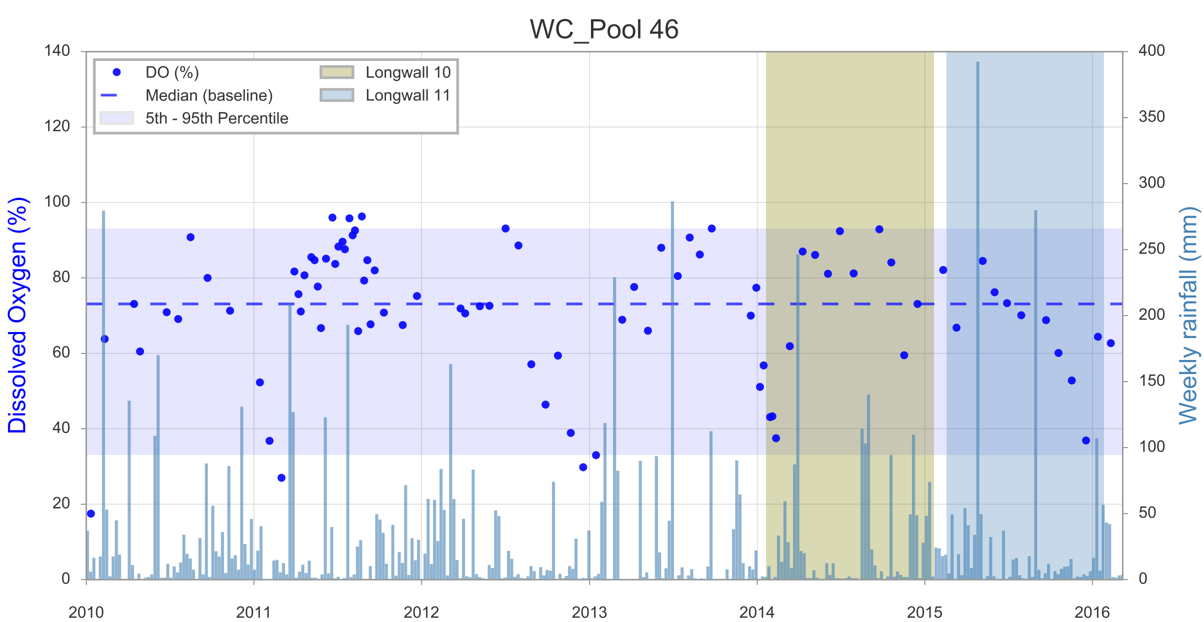

WC_Pool 43b
DO (%)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Dissolved Oxygen (%)
Weekly rainfall (mm)
2010
2011
2012
2013
2014
2015
2016



WC_Pool 46
EC (uS/cm)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Electrical Conductivity (uS/cm)
Weekly rainfall (mm)
0
50
100
150
200
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016



WC_Pool 46
pH
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
pH units
Weekly rainfall (mm)
3
4
5
6
7
8
9
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016



WC_Pool 46
DO (%)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Dissolved Oxygen (%)
Weekly rainfall (mm)
0
20
40
60
80
100
120
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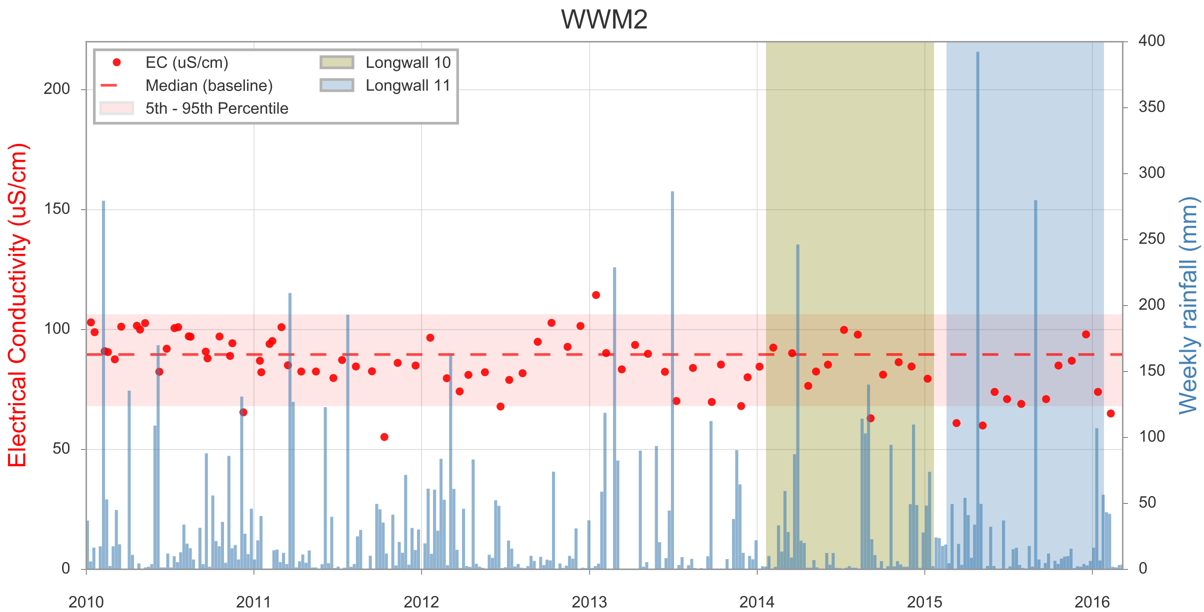
2012
2013
2014
2015
2016


WWM2
EC (uS/cm)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Electrical Conductivity (uS/cm)
Weekly rainfall (mm)
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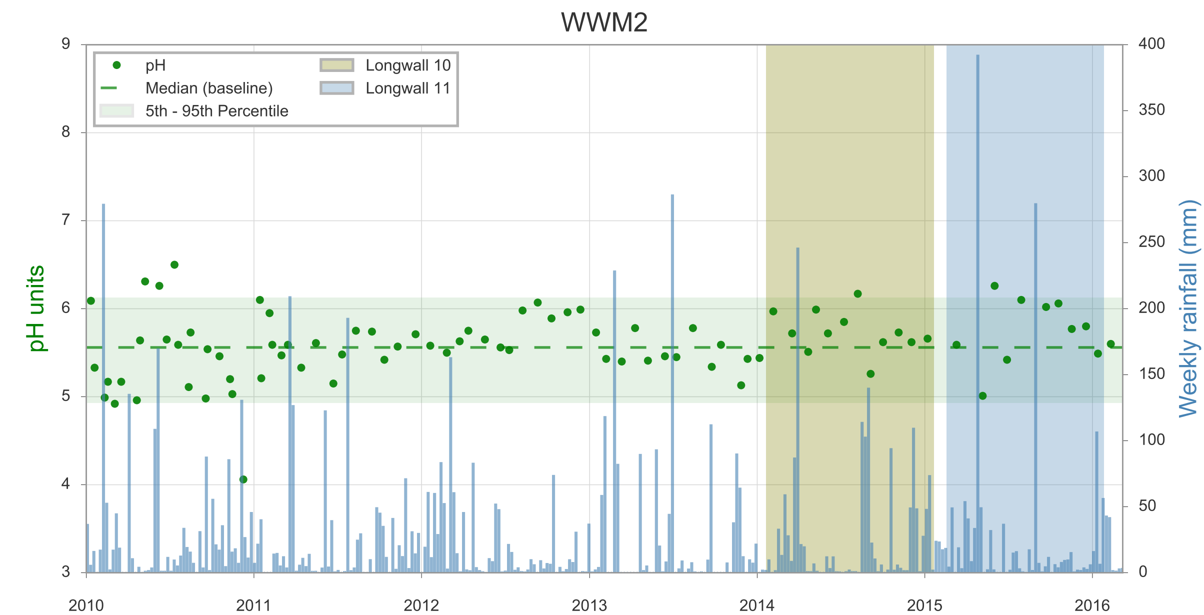
2011
2012
2013
2014
2015
2016


WWM2
pH
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
pH units
Weekly rainfall (mm)
3
4
5
6
7
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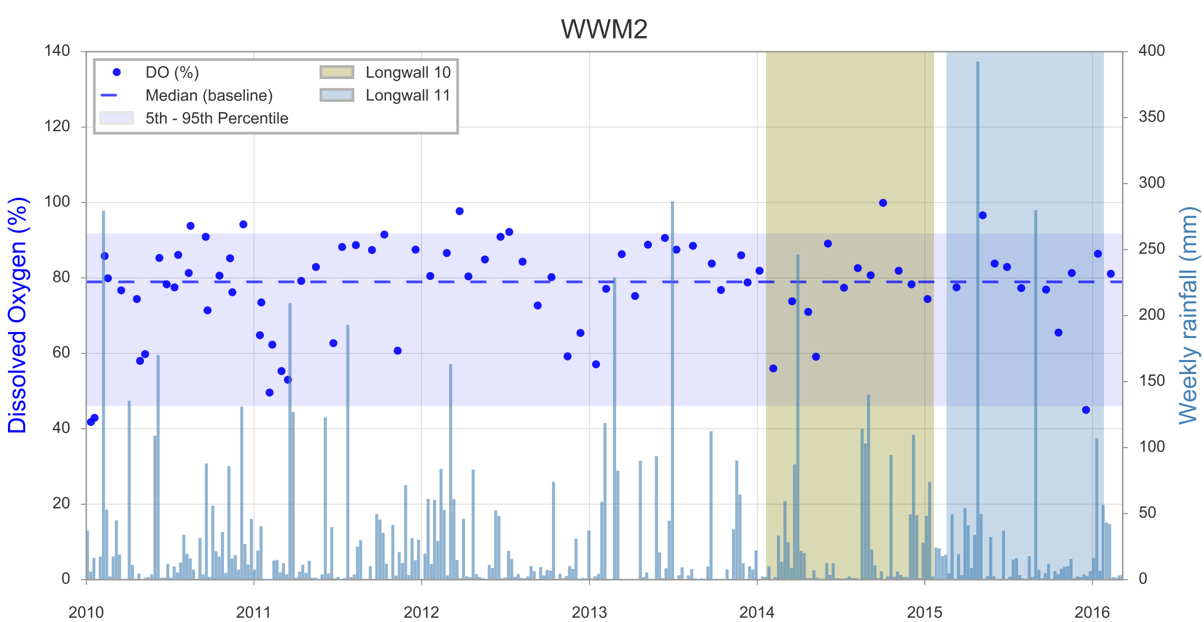
2012
2013
2014
2015
2016


WWM2
DO (%)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Dissolved Oxygen (%)
Weekly rainfall (mm)
0
20
40
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250
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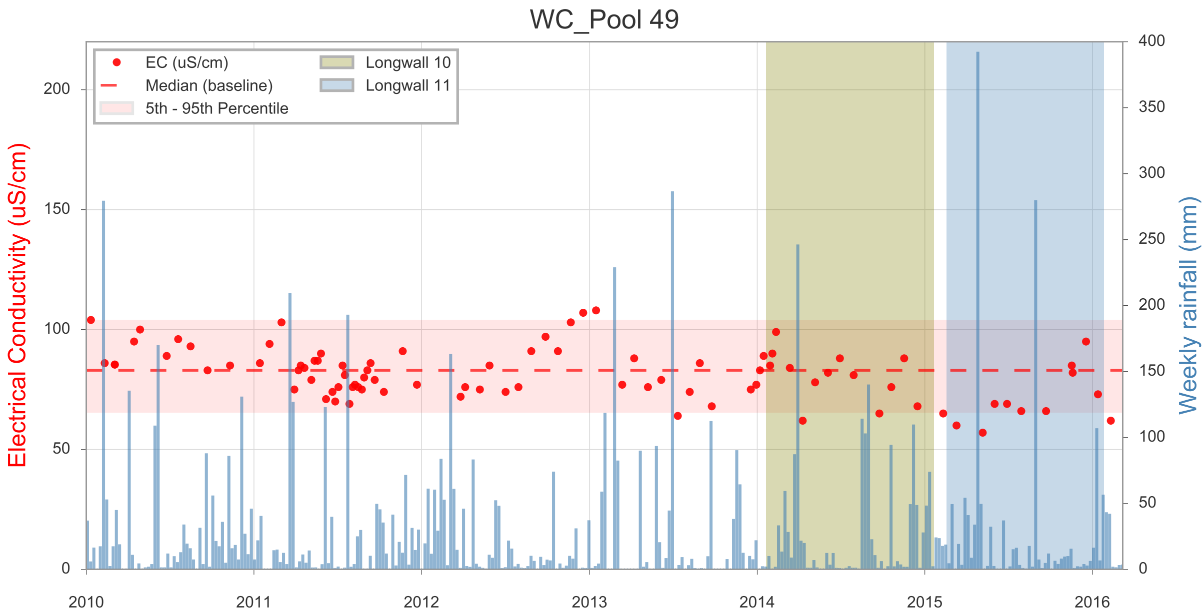
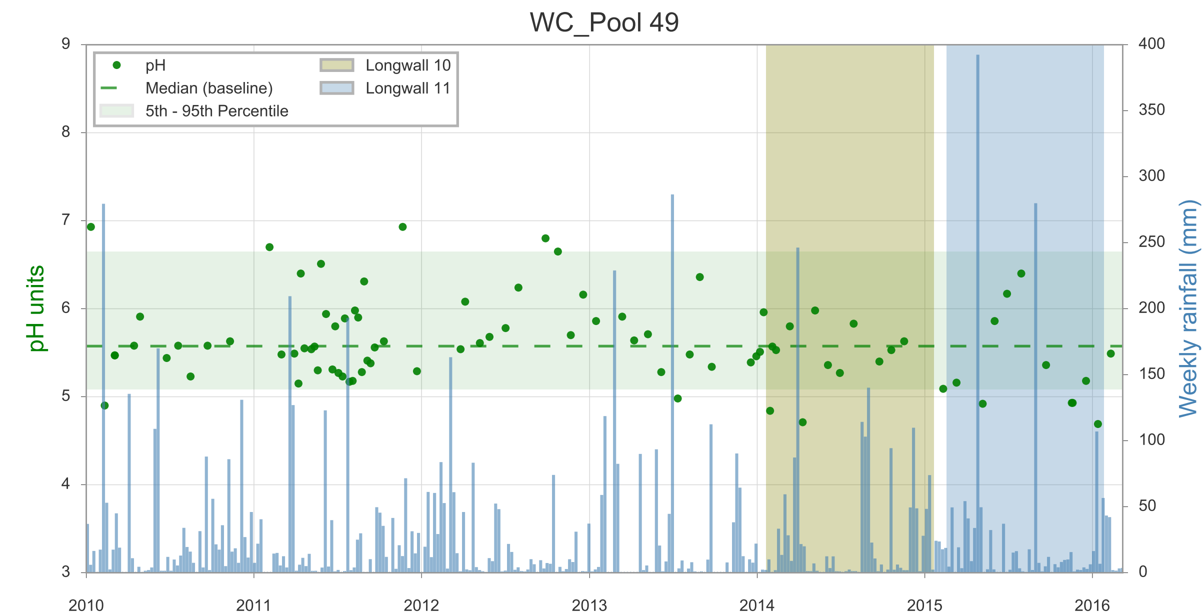
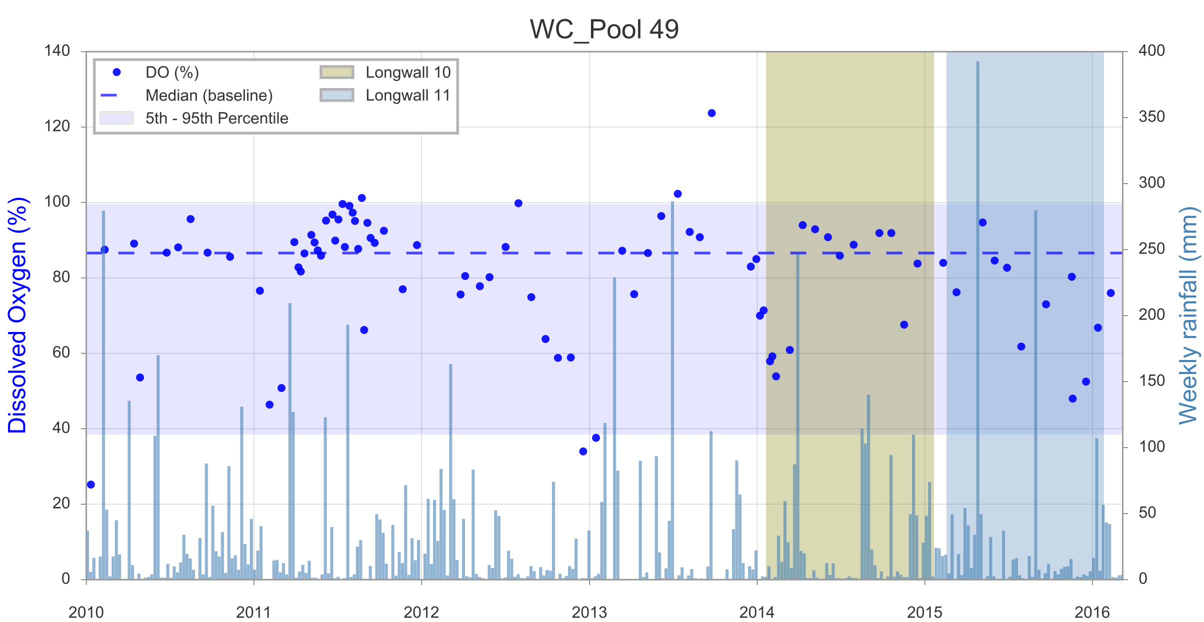
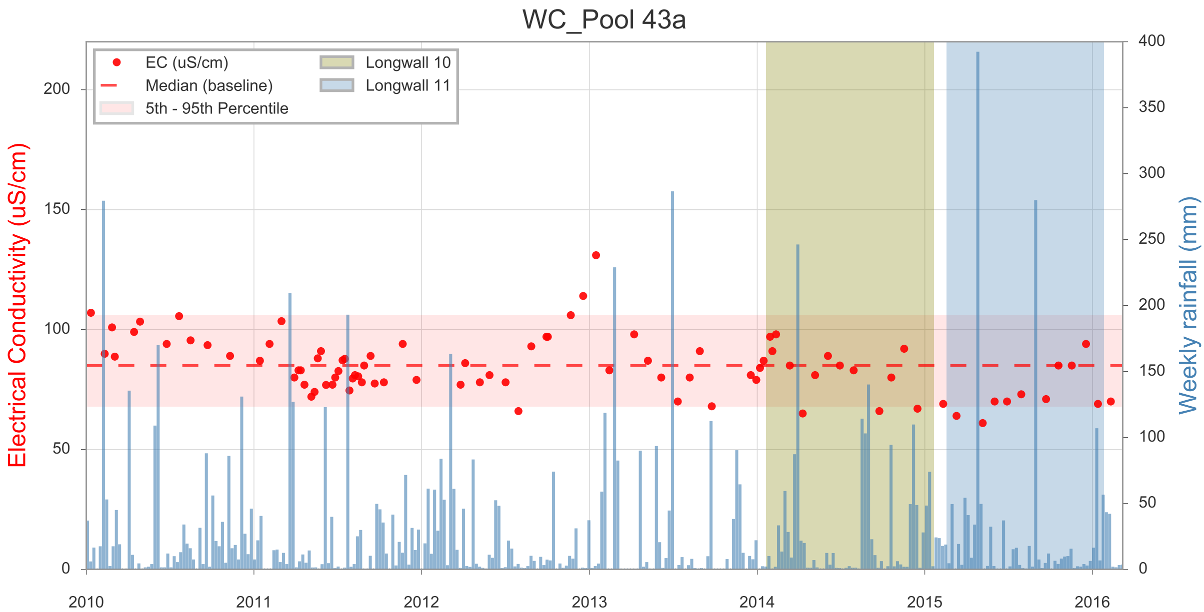
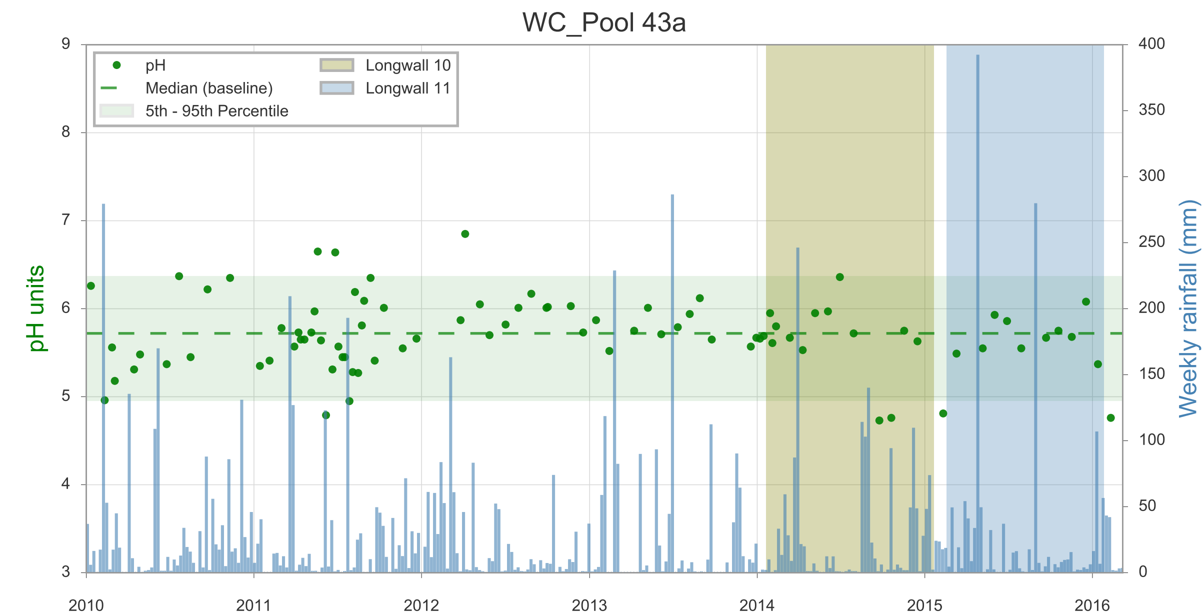
2011
2012
2013
2014
2015
2016

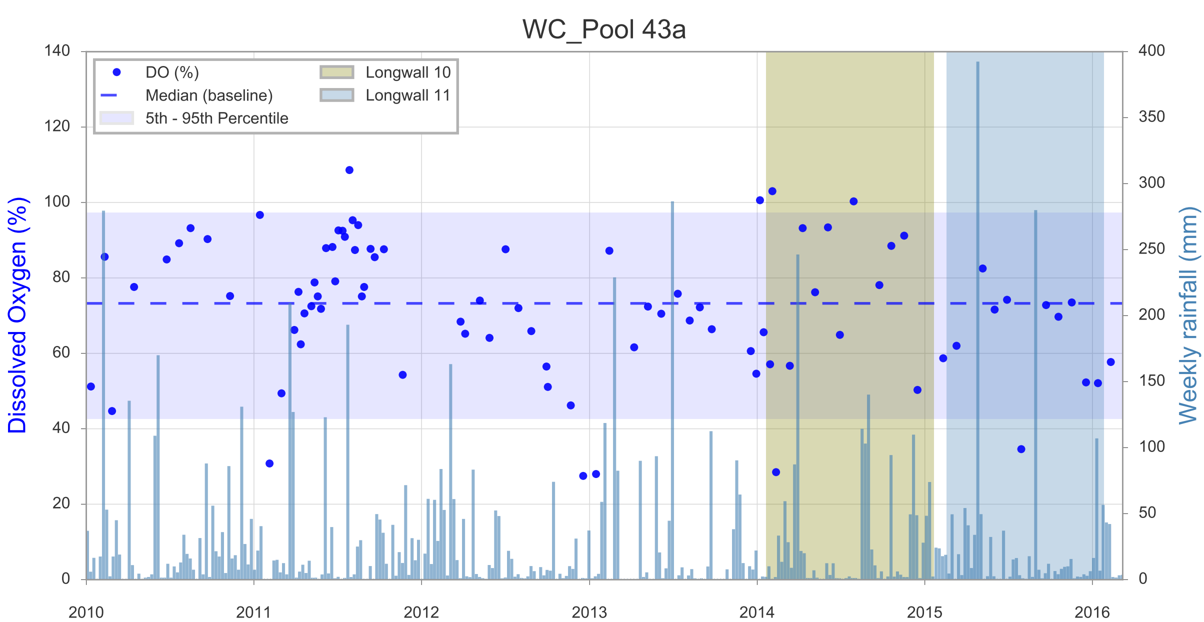

WC_Pool 49
EC (uS/cm)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Electrical Conductivity (uS/cm)
Weekly rainfall (mm)

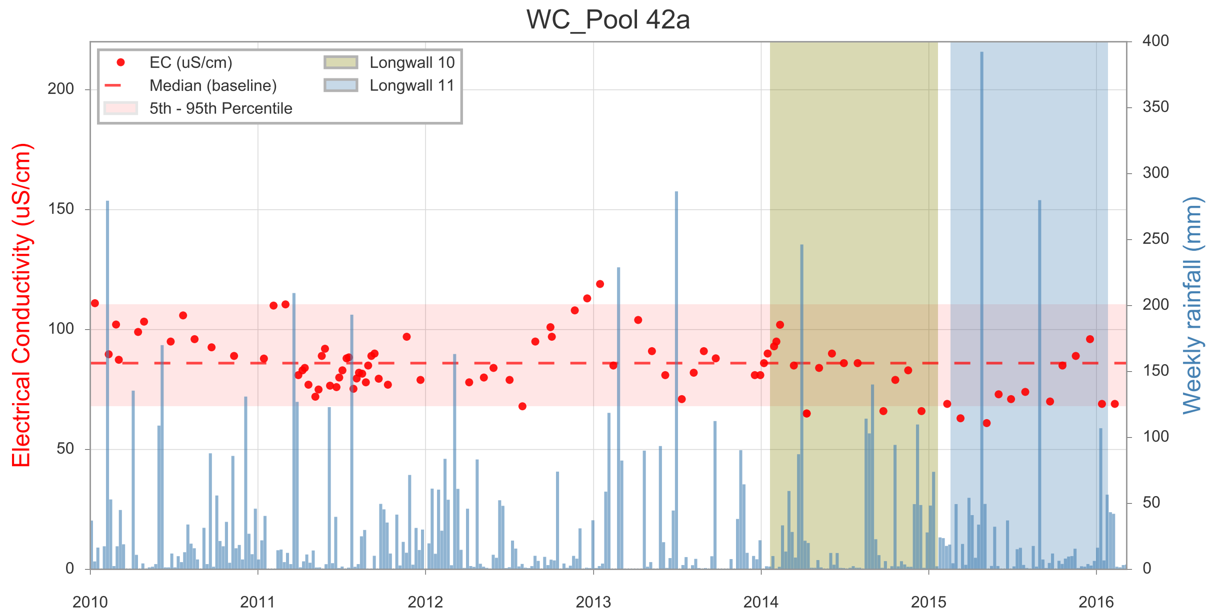

WC_Pool 49
pH
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
pH units
Weekly rainfall (mm)

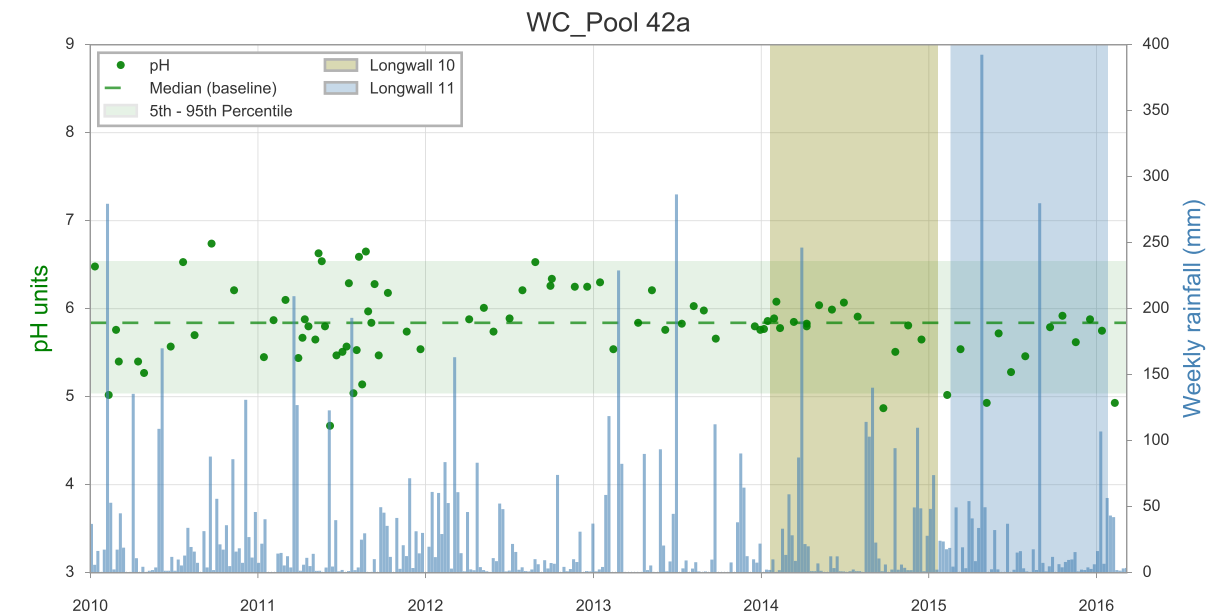

WC_Pool 49
DO (%)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Dissolved Oxygen (%)
Weekly rainfall (mm)

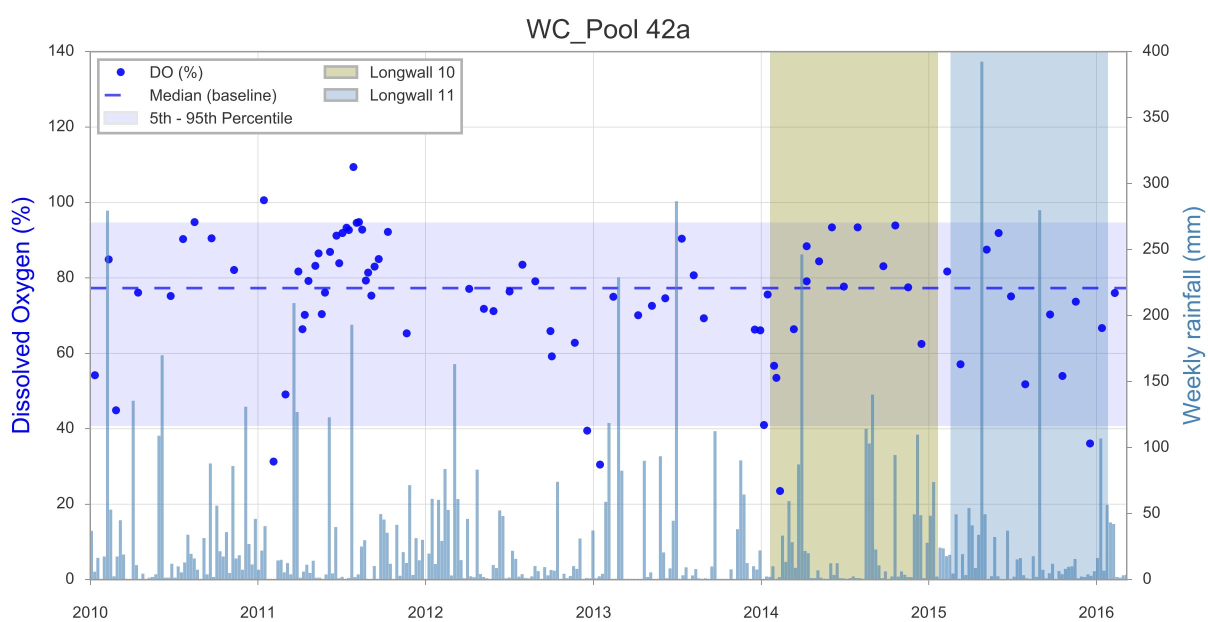

WC_Pool 43a
EC (uS/cm)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Electrical Conductivity (uS/cm)
Weekly rainfall (mm)

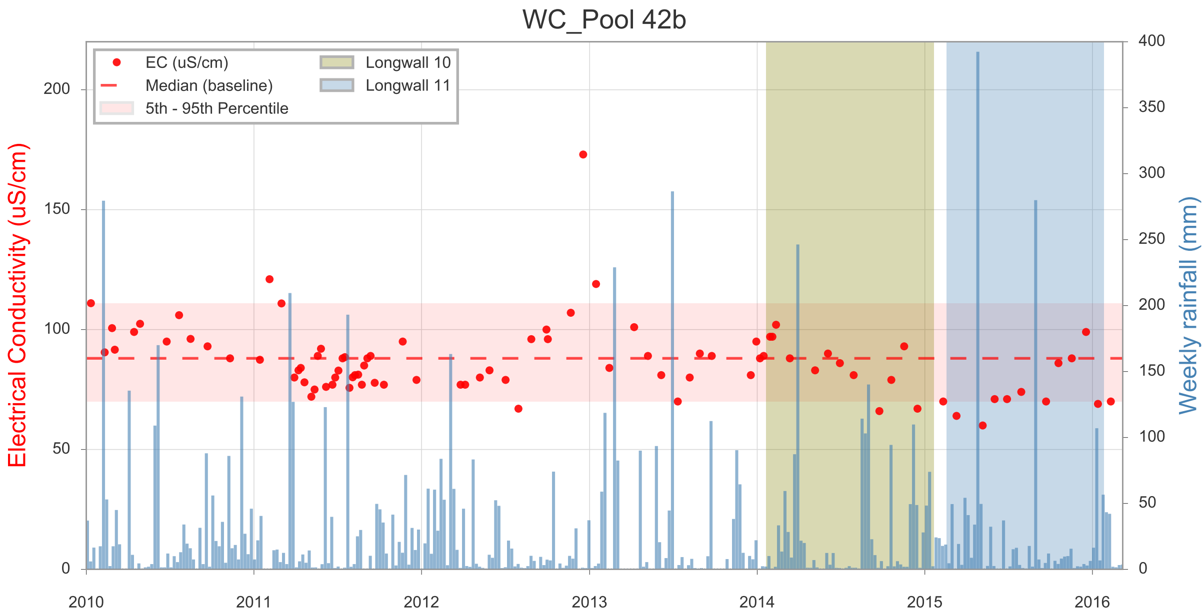

WC_Pool 43a
pH
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
pH units
Weekly rainfall (mm)

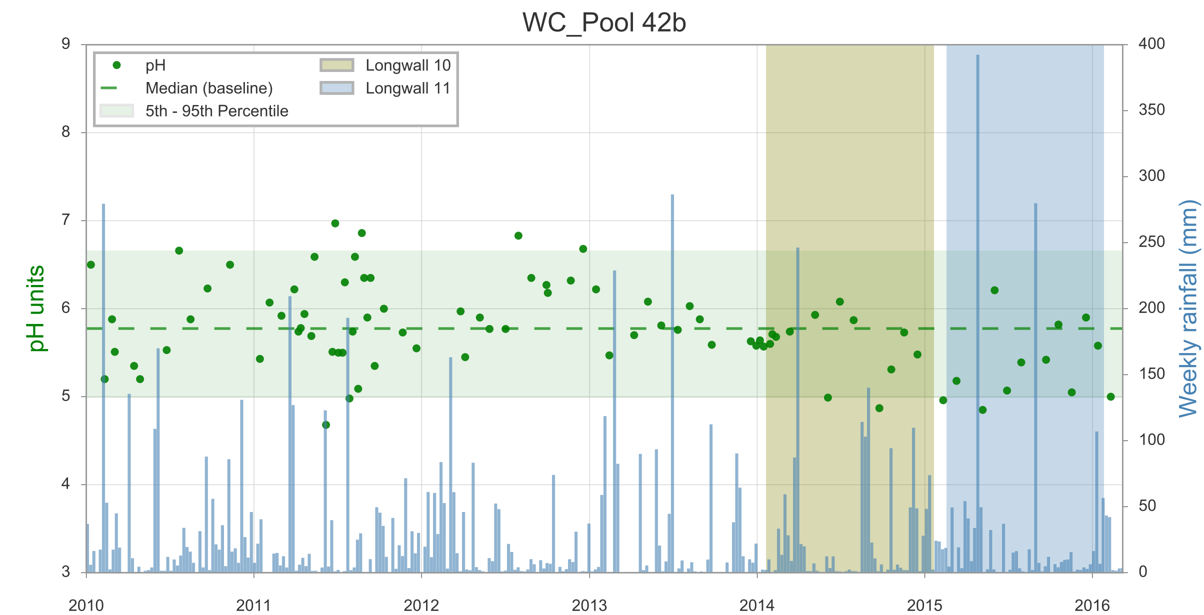

WC_Pool 43a
DO (%)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Dissolved Oxygen (%)
Weekly rainfall (mm)


WC_Pool 42a
EC (uS/cm)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Electrical Conductivity (uS/cm)
Weekly rainfall (mm)
0
50
100
150
200
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016


WC_Pool 42a
pH
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
pH units
Weekly rainfall (mm)
3
4
5
6
7
8
9
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016


WC_Pool 42a
DO (%)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Dissolved Oxygen (%)
Weekly rainfall (mm)
0
20
40
60
80
100
120
140
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016


WC_Pool 42b
EC (uS/cm)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Electrical Conductivity (uS/cm)
Weekly rainfall (mm)
0
50
100
150
200
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016


WC_Pool 42b
pH
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
pH units
Weekly rainfall (mm)
3
4
5
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2010
2011
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2015
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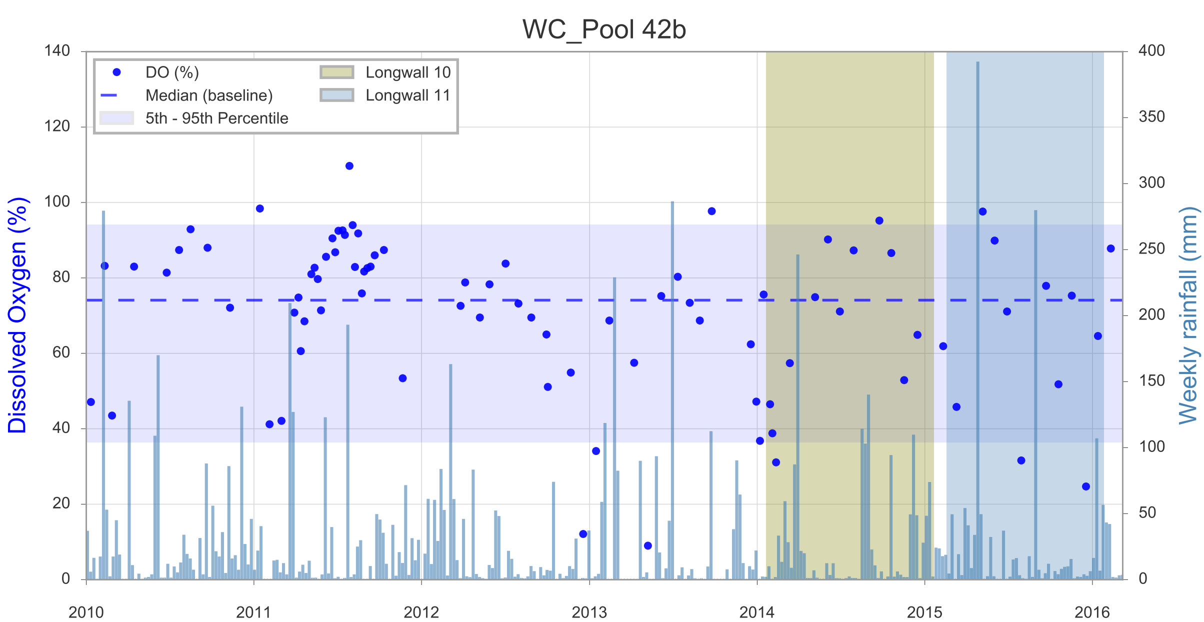
WC_Pool 42b
DO (%)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Dissolved Oxygen (%)
Weekly rainfall (mm)
0
20
40
60
80
100
120
140
0
50
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2010
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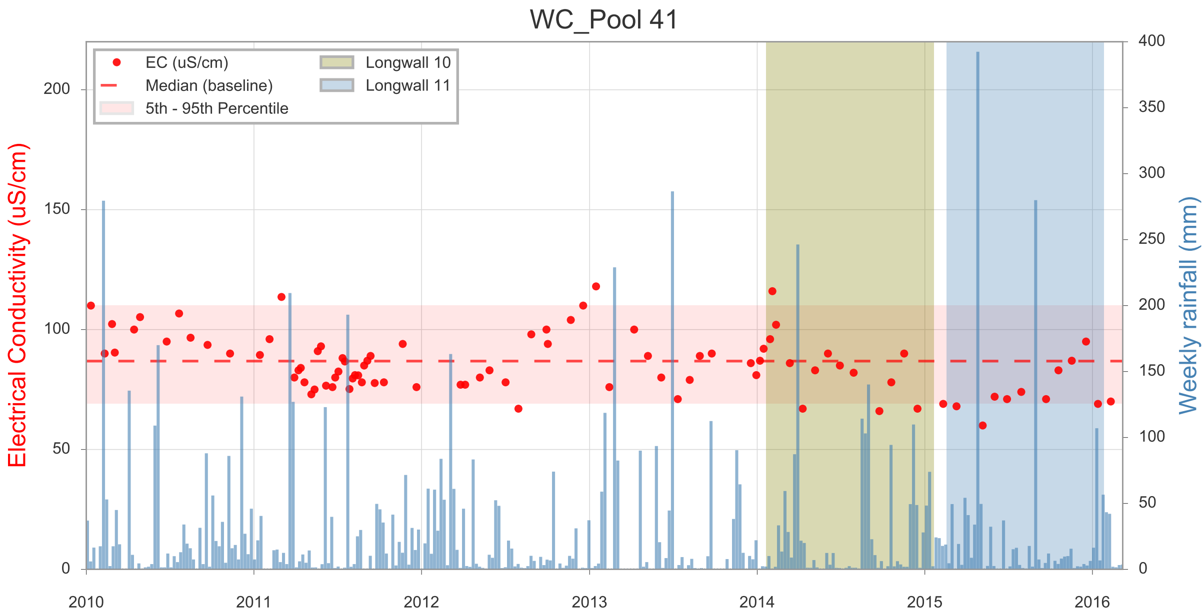
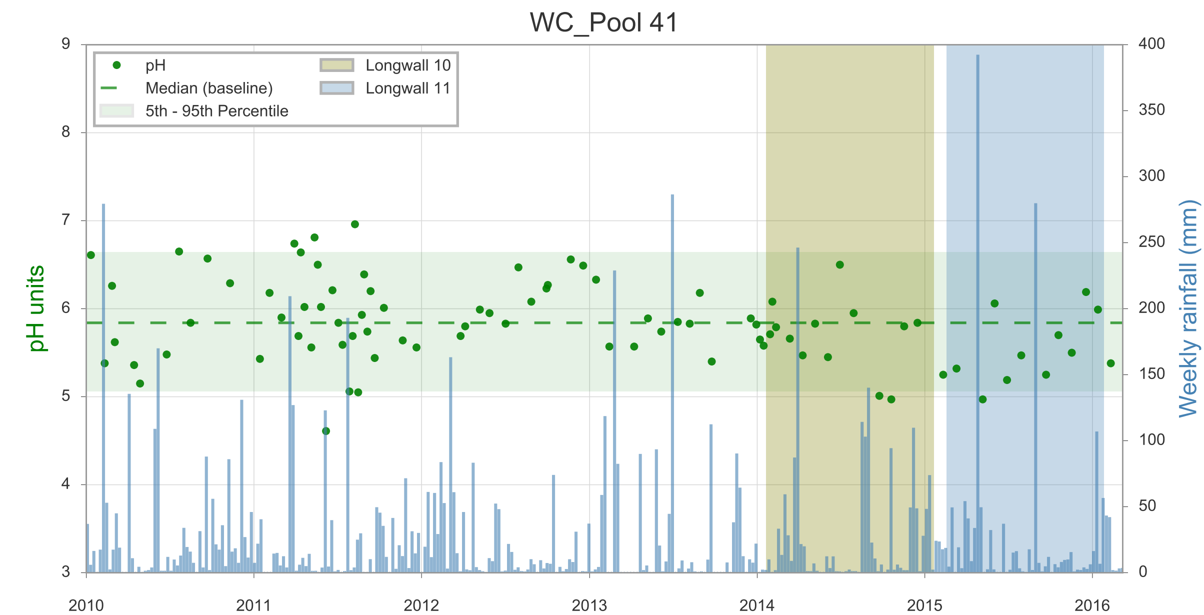
2016


WC_Pool 41
EC (uS/cm)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Electrical Conductivity (uS/cm)
Weekly rainfall (mm)
0
50
100
150
200
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016


WC_Pool 41
pH
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
pH units
Weekly rainfall (mm)
3
4
5
6
7
8
9
0
50
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200
250
300
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400
2010
2011
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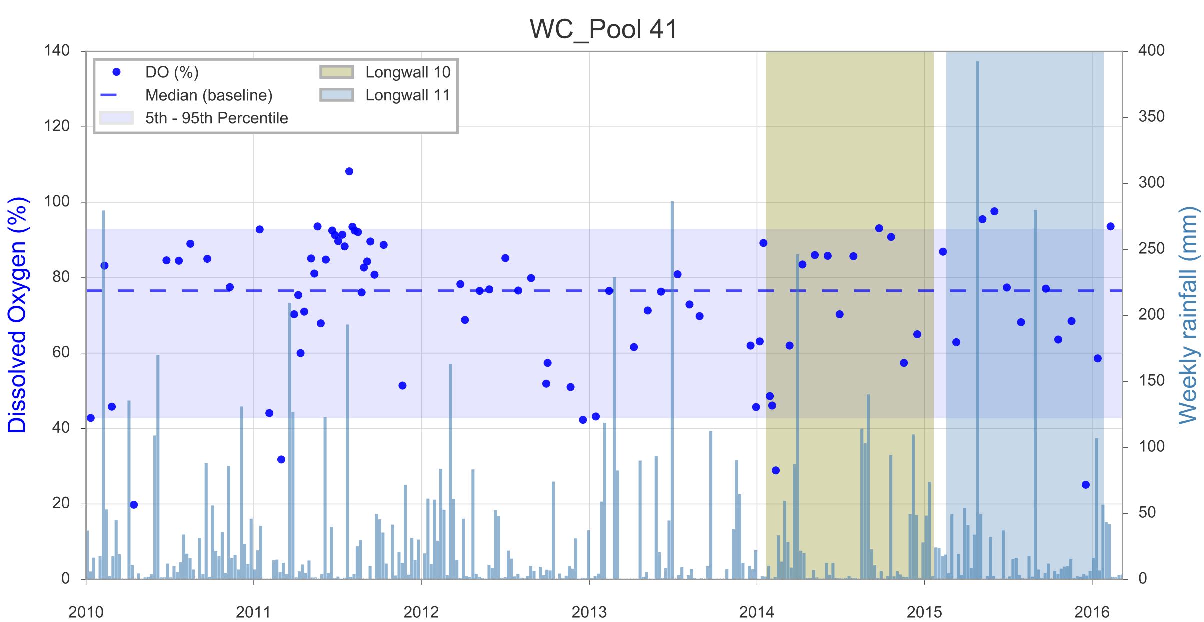
2013
2014
2015
2016


WC_Pool 41
DO (%)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Dissolved Oxygen (%)
Weekly rainfall (mm)
0
20
40
60
80
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2010
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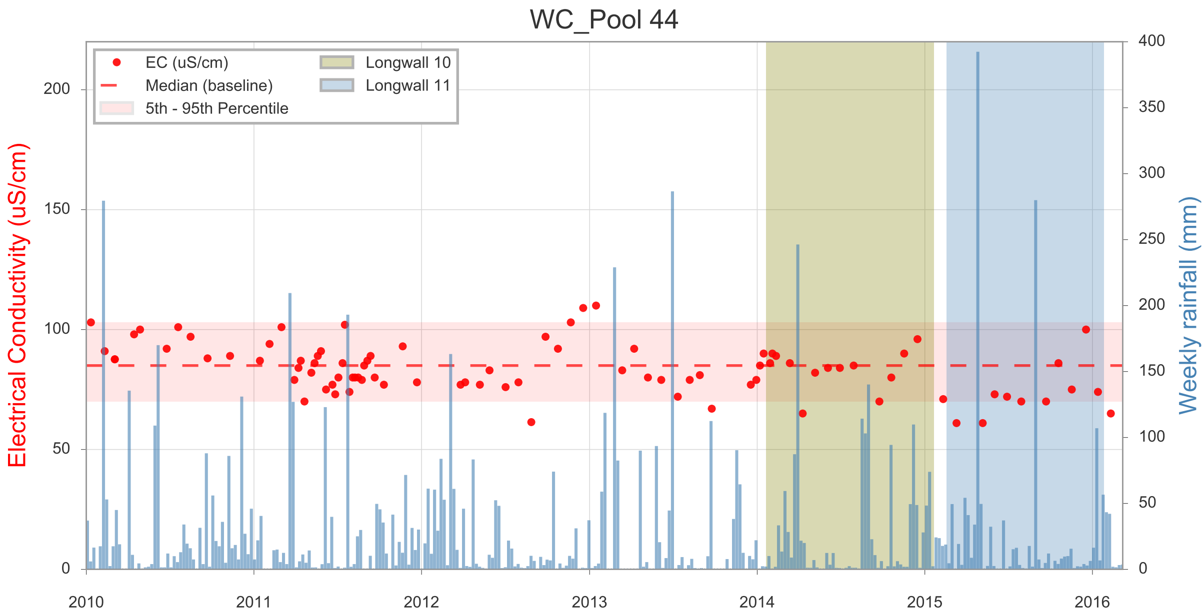
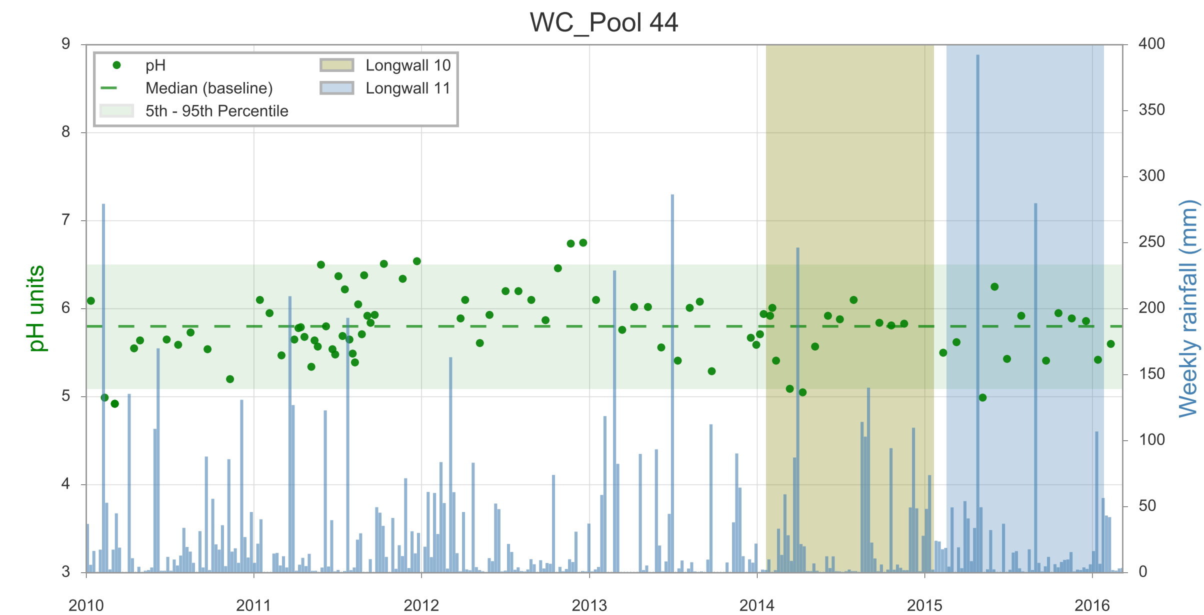

WC_Pool 44
EC (uS/cm)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Electrical Conductivity (uS/cm)
Weekly rainfall (mm)
0
50
100
150
200
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016


WC_Pool 44
pH
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
pH units
Weekly rainfall (mm)
3
4
5
6
7
8
9
0
50
100
150
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2010
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2014
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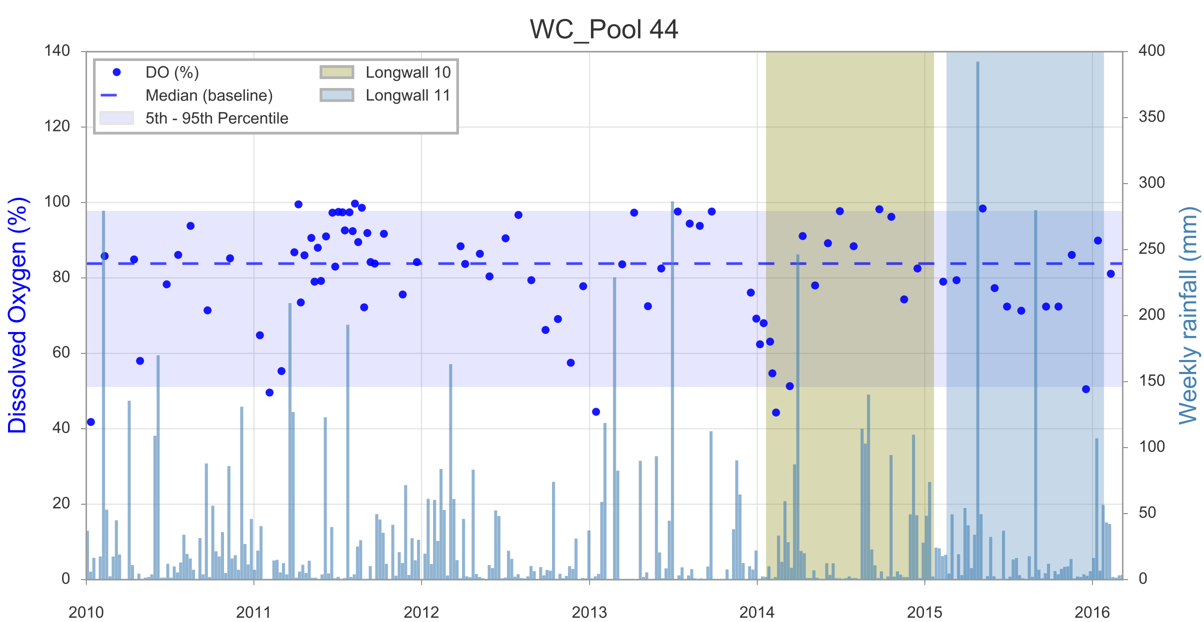
2016


WC_Pool 44
DO (%)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Dissolved Oxygen (%)
Weekly rainfall (mm)
0
20
40
60
80
100
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2010
2011
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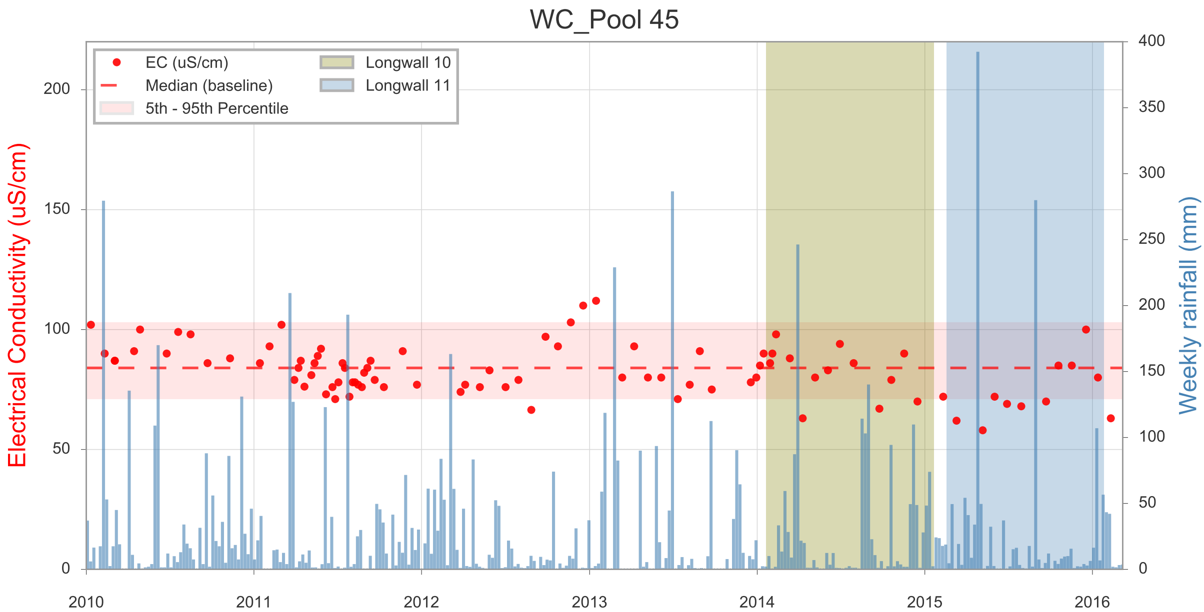
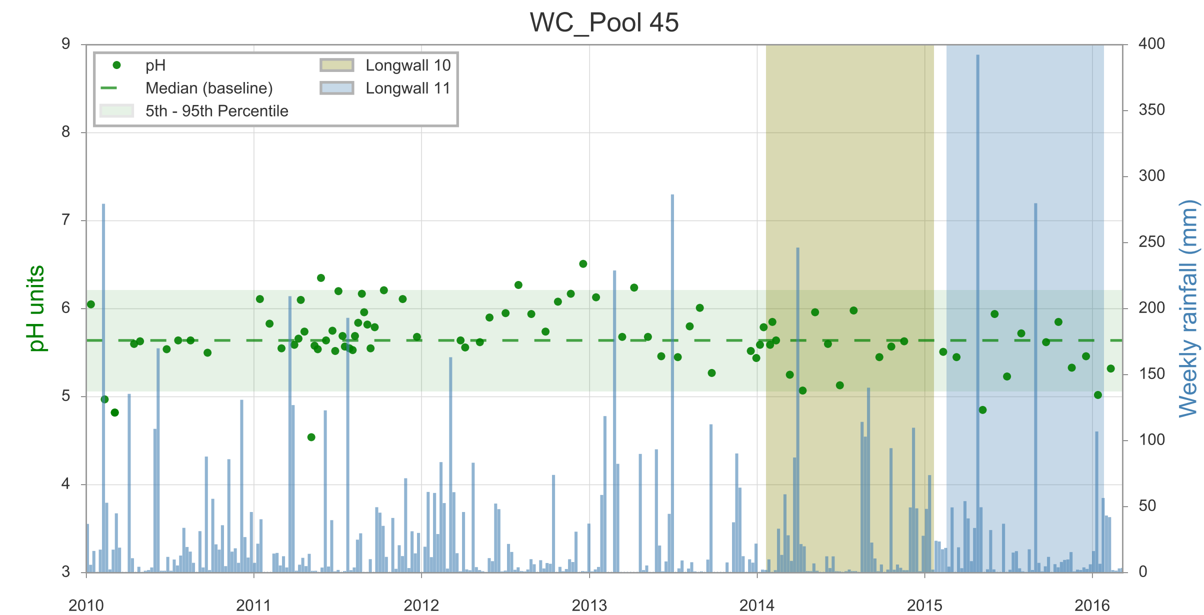
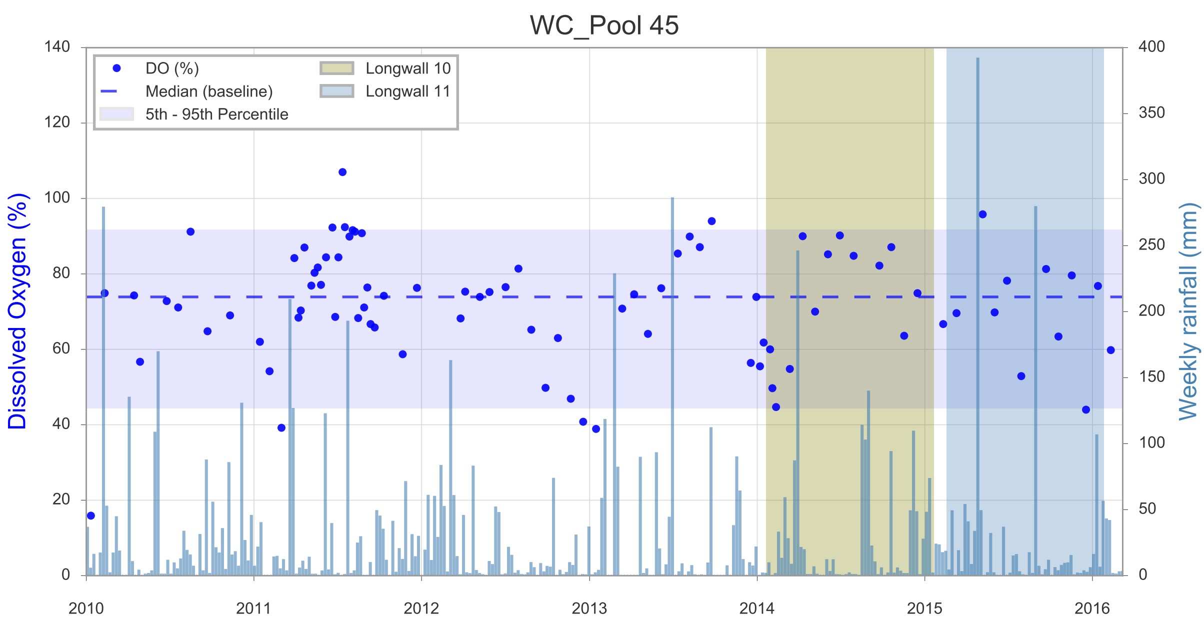
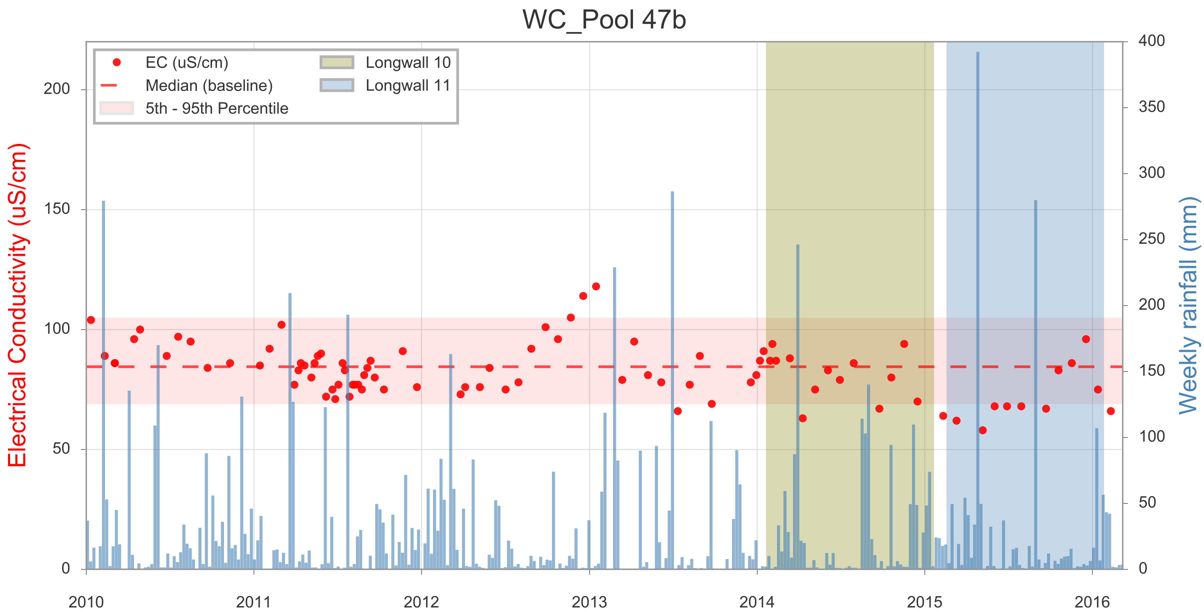
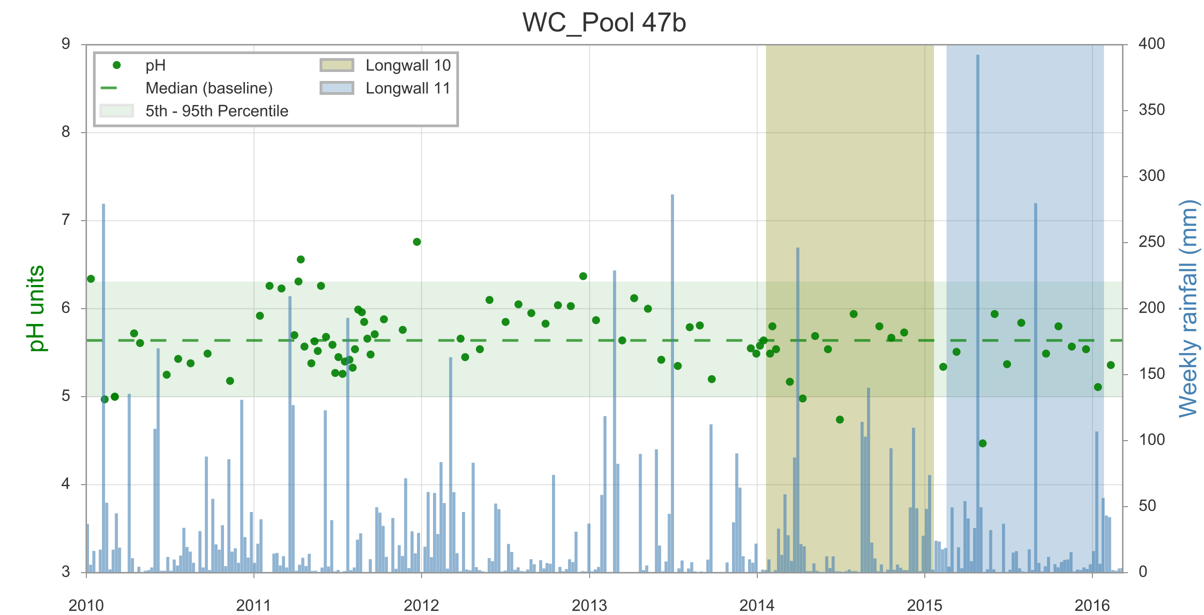
2015
2016


WC_Pool 45
EC (uS/cm)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Electrical Conductivity (uS/cm)
Weekly rainfall (mm)
2010
2011
2012
2013
2014
2015
2016


WC_Pool 45
pH
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
pH units
Weekly rainfall (mm)
2010
2011
2012
2013
2014
2015
2016


WC_Pool 45
DO (%)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Dissolved Oxygen (%)
Weekly rainfall (mm)
2010
2011
2012
2013
2014
2015
2016


WC_Pool 47b
EC (uS/cm)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Electrical Conductivity (uS/cm)
Weekly rainfall (mm)
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016


WC_Pool 47b
pH
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
pH units
Weekly rainfall (mm)
3
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6
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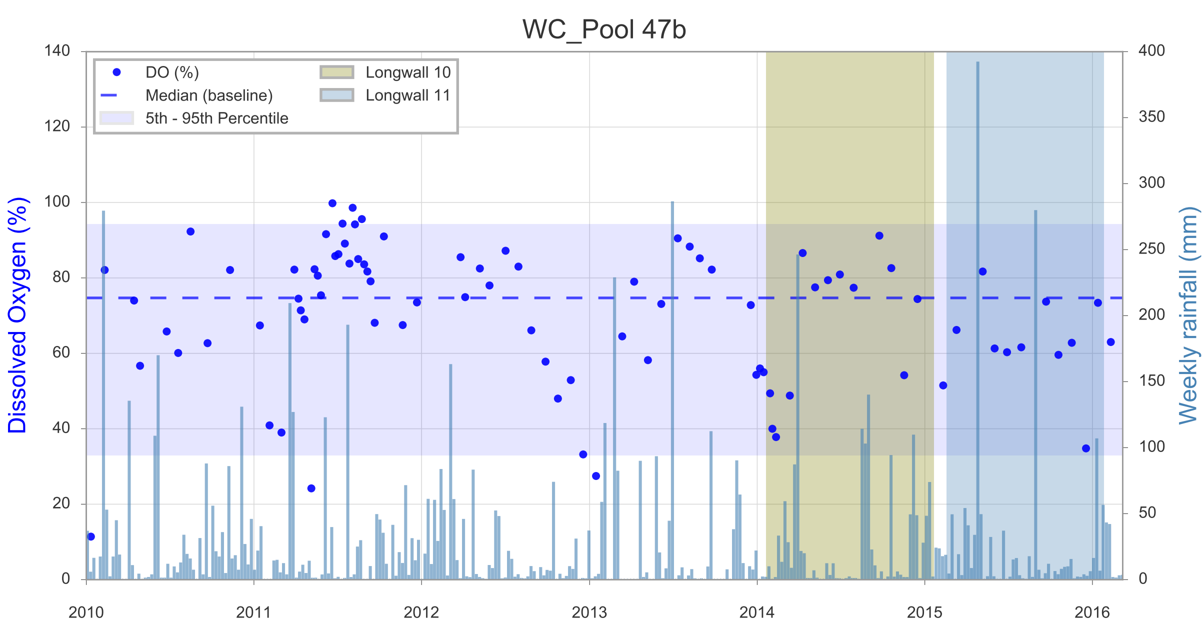
8
9
2010
2011
2012
2013
2014
2015
2016


WC_Pool 47b
DO (%)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Dissolved Oxygen (%)
Weekly rainfall (mm)
0
20
40
60
80
100
120
140
2010
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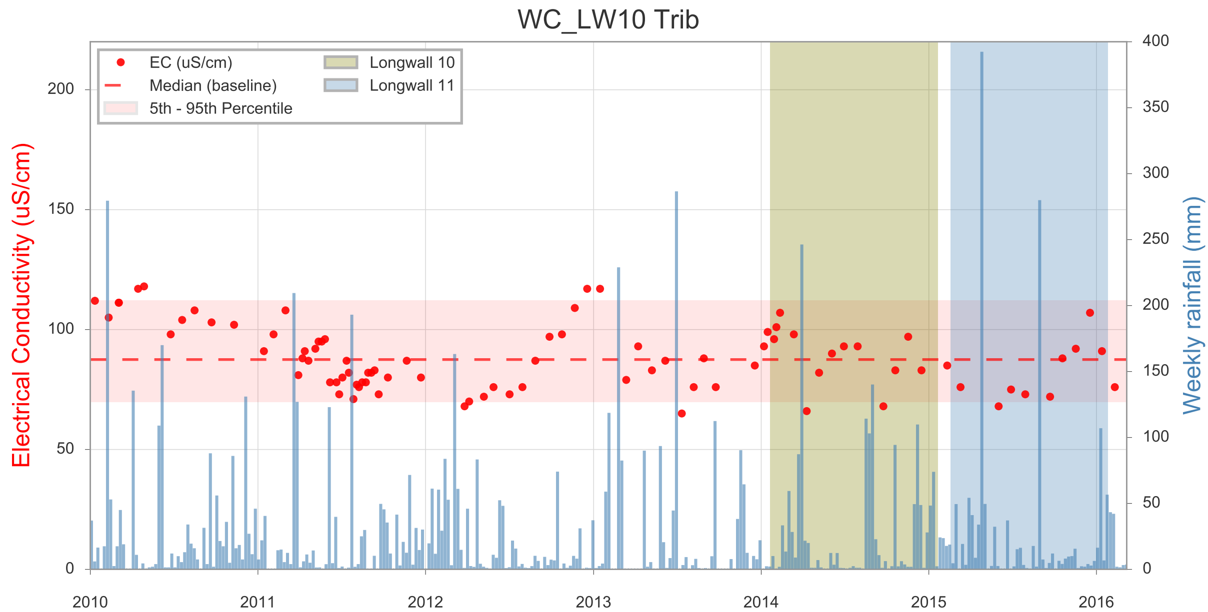
2012
2013
2014
2015
2016


WC_LW10 Trib
EC (uS/cm)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Electrical Conductivity (uS/cm)
Weekly rainfall (mm)
0
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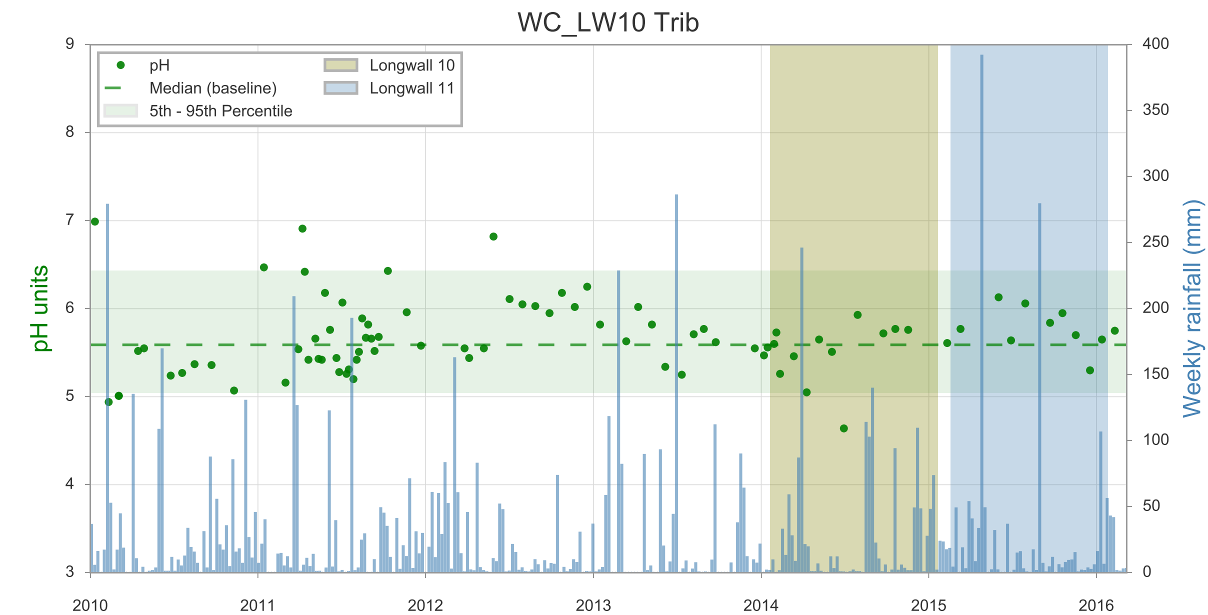
100
150
200
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016


WC_LW10 Trib
pH
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
pH units
Weekly rainfall (mm)
3
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2010
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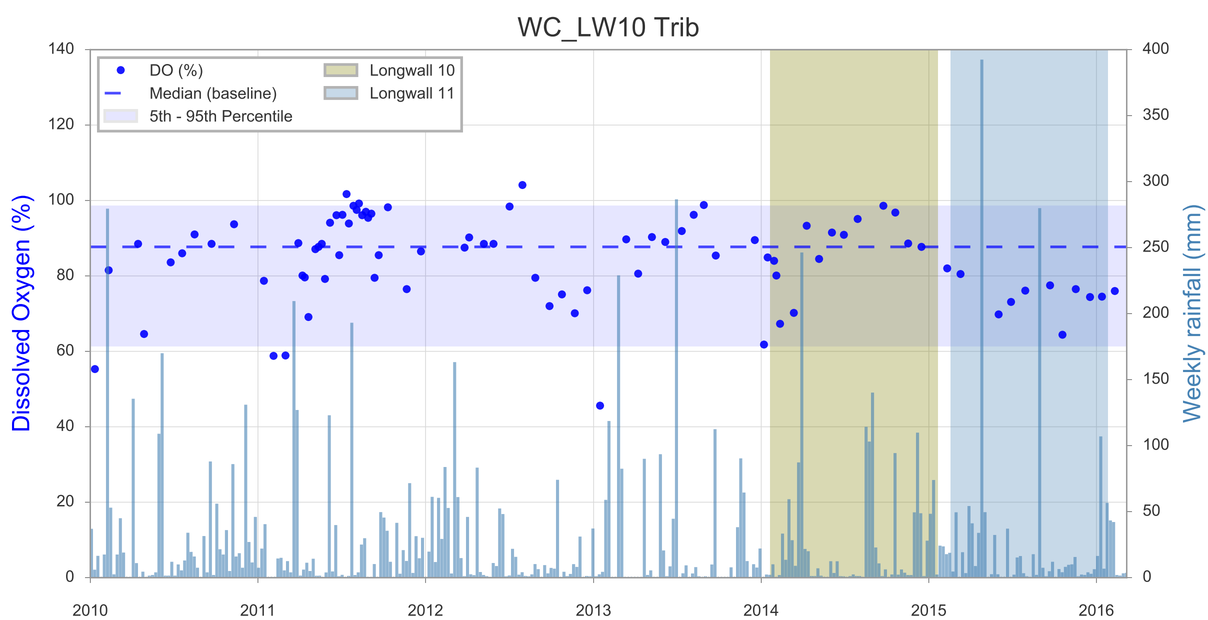
2015
2016


WC_LW10 Trib
DO (%)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Dissolved Oxygen (%)
Weekly rainfall (mm)
0
20
40
60
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120
140
0
50
100
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250
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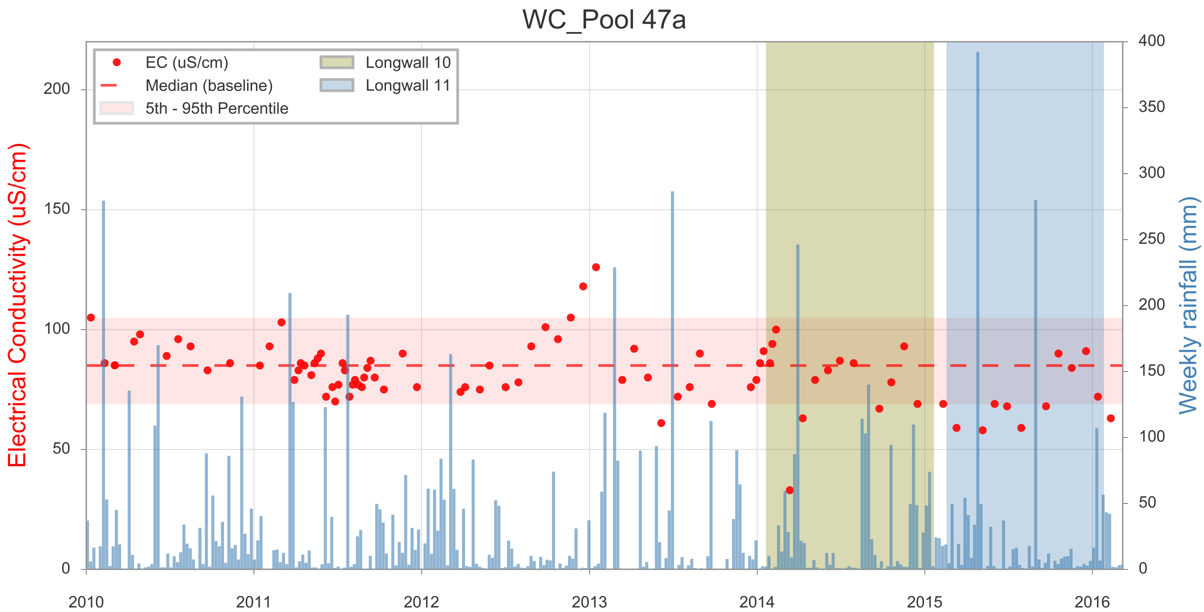
400
2010
2011
2012
2013
2014
2015
2016


WC_Pool 47a
EC (uS/cm)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Electrical Conductivity (uS/cm)
Weekly rainfall (mm)
0
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100
150
200
0
50
100
150
200
250
300
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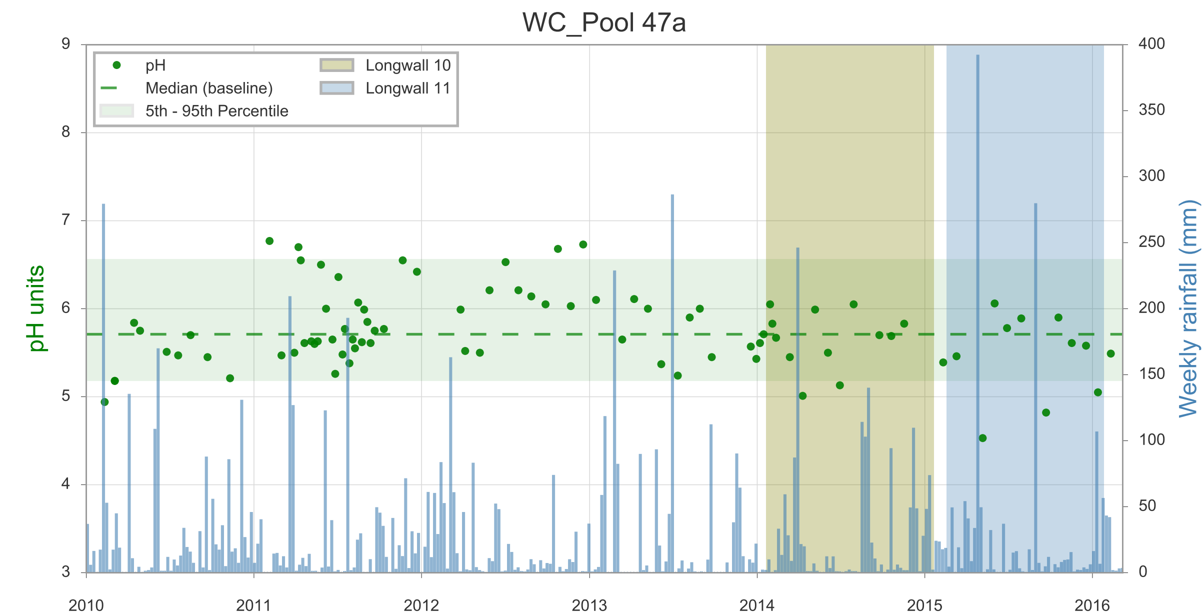
400
2010
2011
2012
2013
2014
2015
2016


WC_Pool 47a
pH
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
pH units
Weekly rainfall (mm)
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2010
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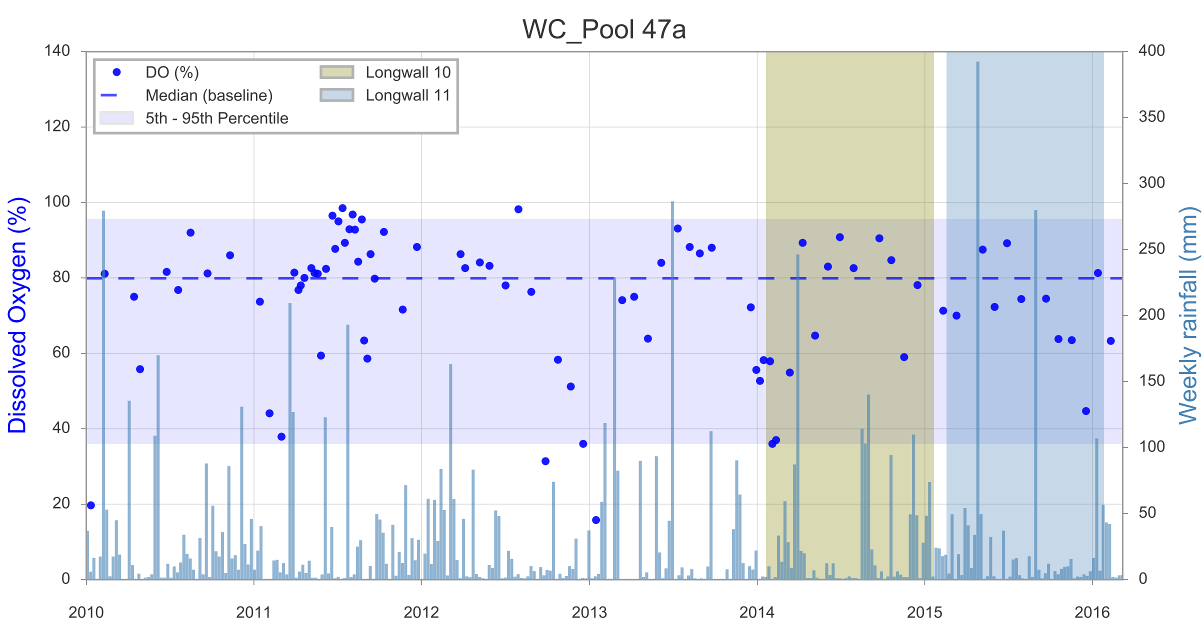
2015
2016


WC_Pool 47a
DO (%)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Dissolved Oxygen (%)
Weekly rainfall (mm)
0
20
40
60
80
100
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2010
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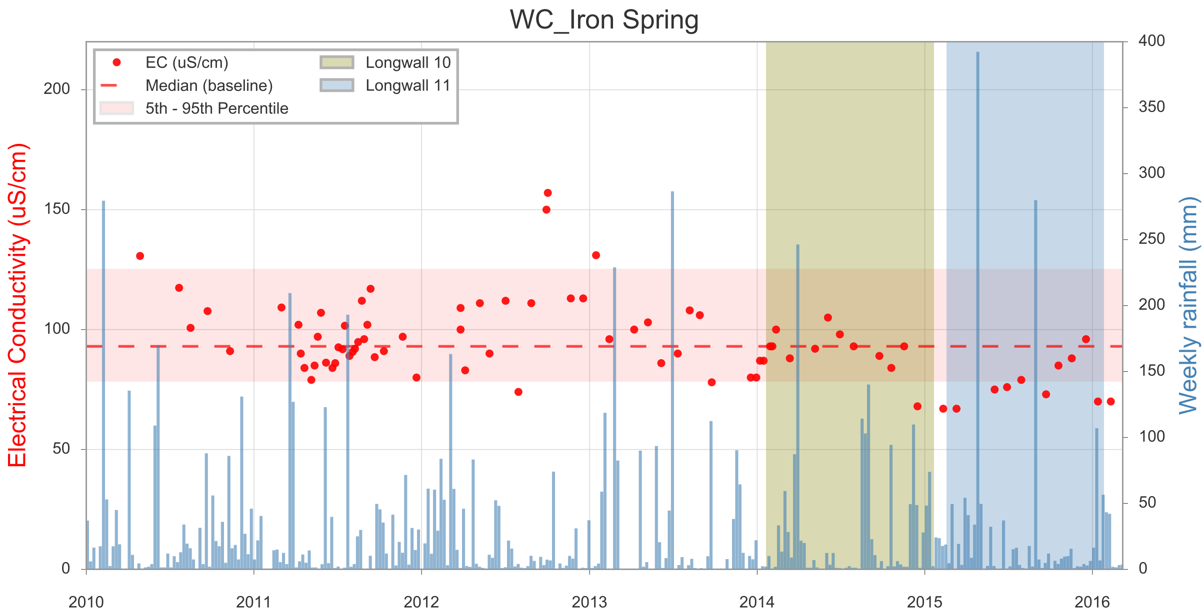
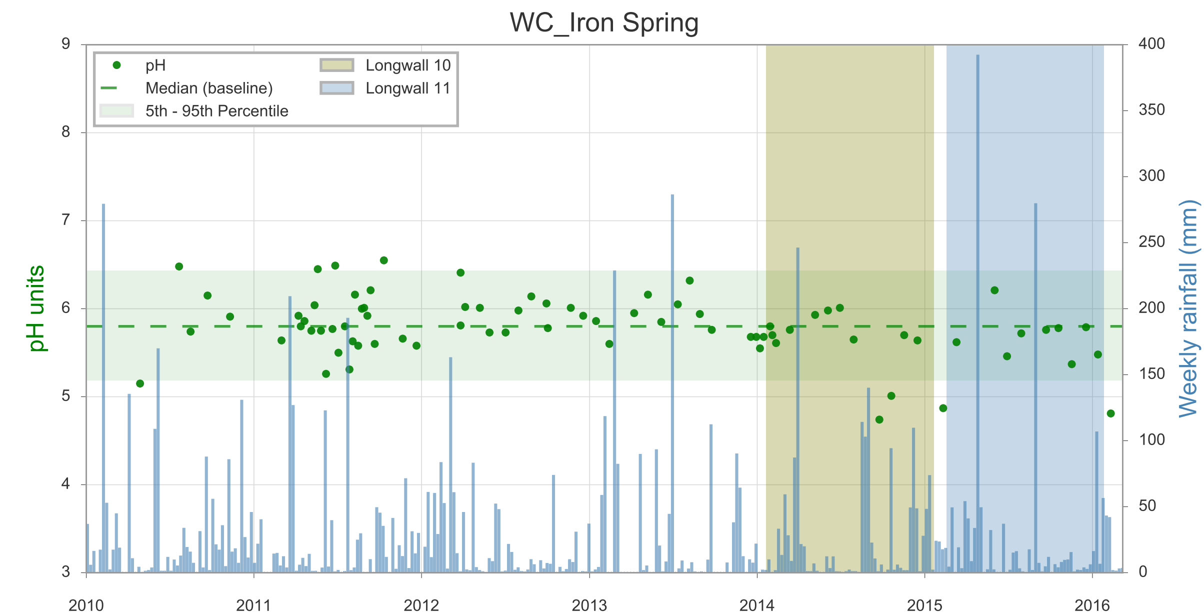
2015
2016


WC_Iron Spring
EC (uS/cm)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Electrical Conductivity (uS/cm)
Weekly rainfall (mm)
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016


WC_Iron Spring
pH
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
pH units
Weekly rainfall (mm)
3
4
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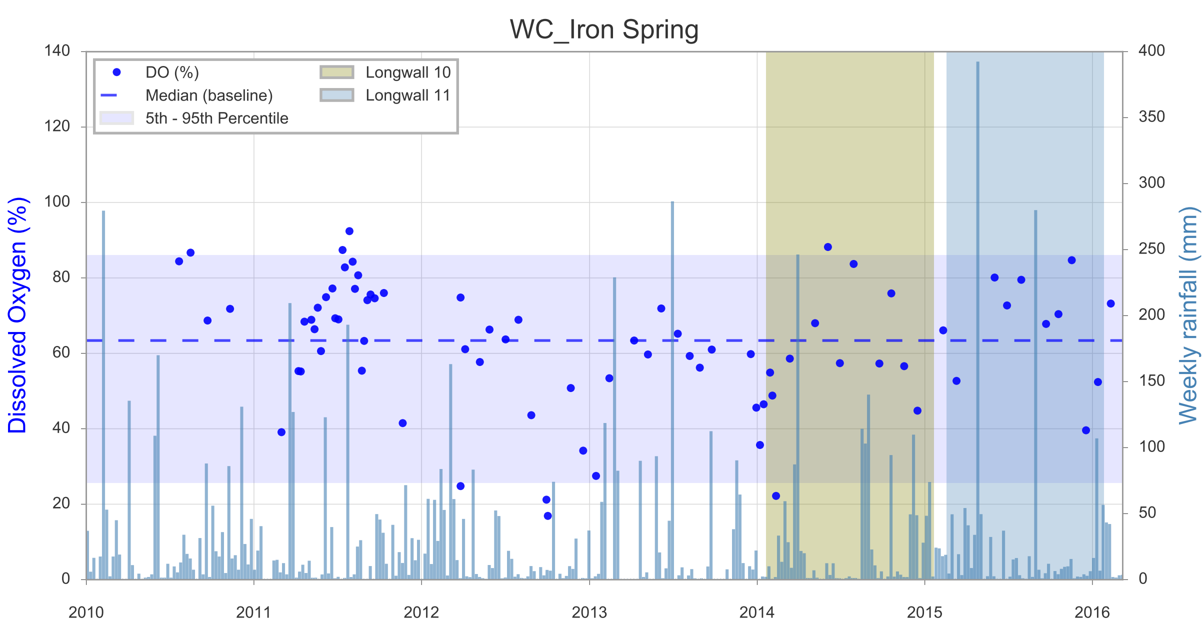
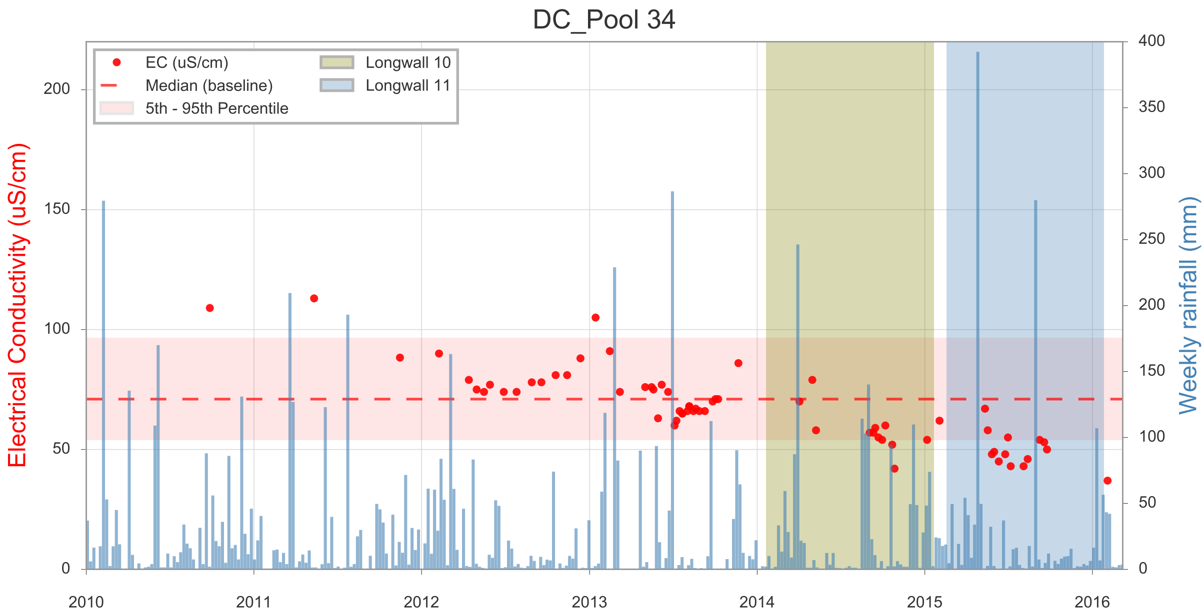
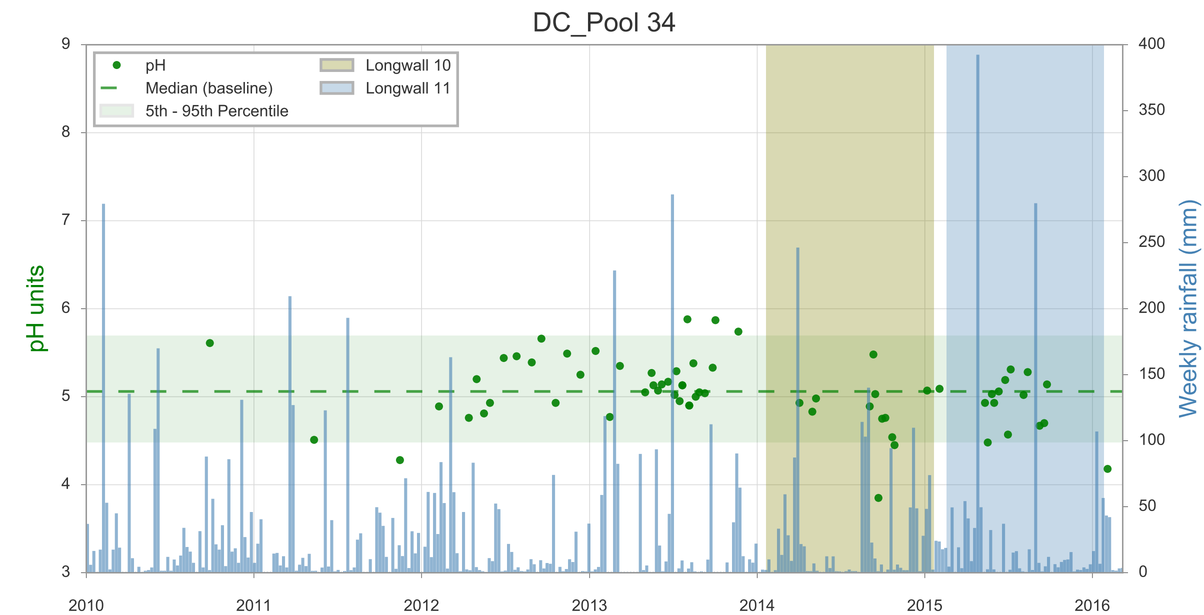
2010
2011
2012
2013
2014
2015
2016


WC_Iron Spring
DO (%)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Dissolved Oxygen (%)
Weekly rainfall (mm)
0
20
40
60
80
100
120
140
2010
2011
2012
2013
2014
2015
2016


DC_Pool 34
EC (uS/cm)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Electrical Conductivity (uS/cm)
Weekly rainfall (mm)
0
50
100
150
200
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016


DC_Pool 34
pH
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
pH units
Weekly rainfall (mm)
3
4
5
6
7
8
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0
50
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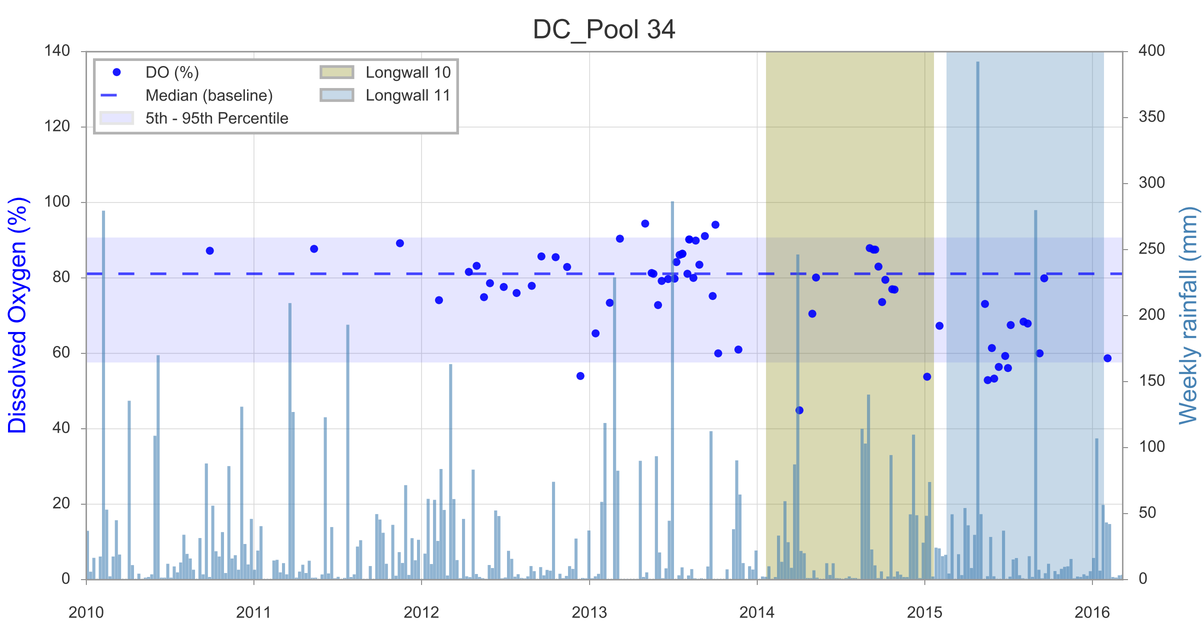
400
2010
2011
2012
2013
2014
2015
2016


DC_Pool 34
DO (%)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Dissolved Oxygen (%)
Weekly rainfall (mm)
0
20
40
60
80
100
120
140
0
50
100
150
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400
2010
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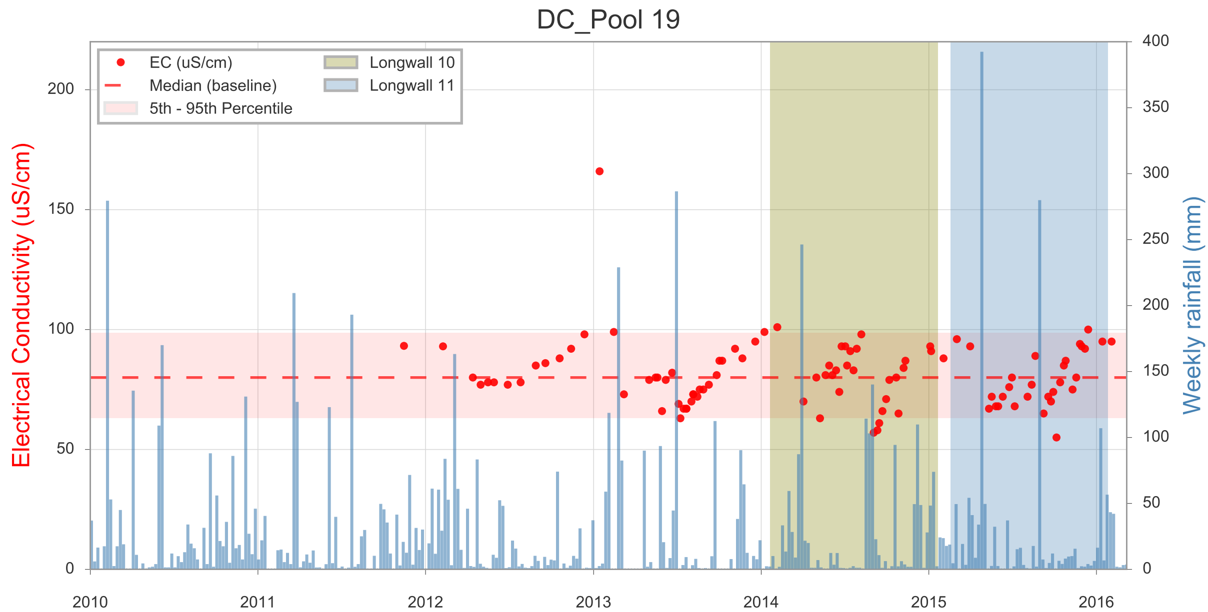
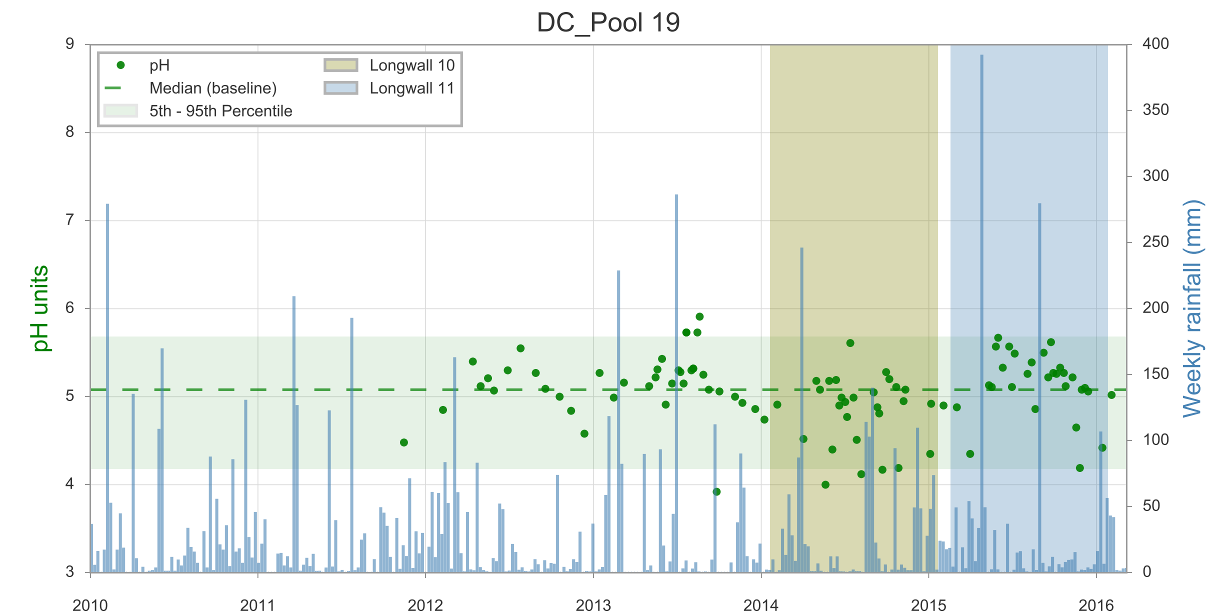
2013
2014
2015
2016



DC_Pool 19
EC (uS/cm)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Electrical Conductivity (uS/cm)
Weekly rainfall (mm)
0
50
100
150
200
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016



DC_Pool 19
pH
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
pH units
Weekly rainfall (mm)
3
4
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0
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2010
2011
2012
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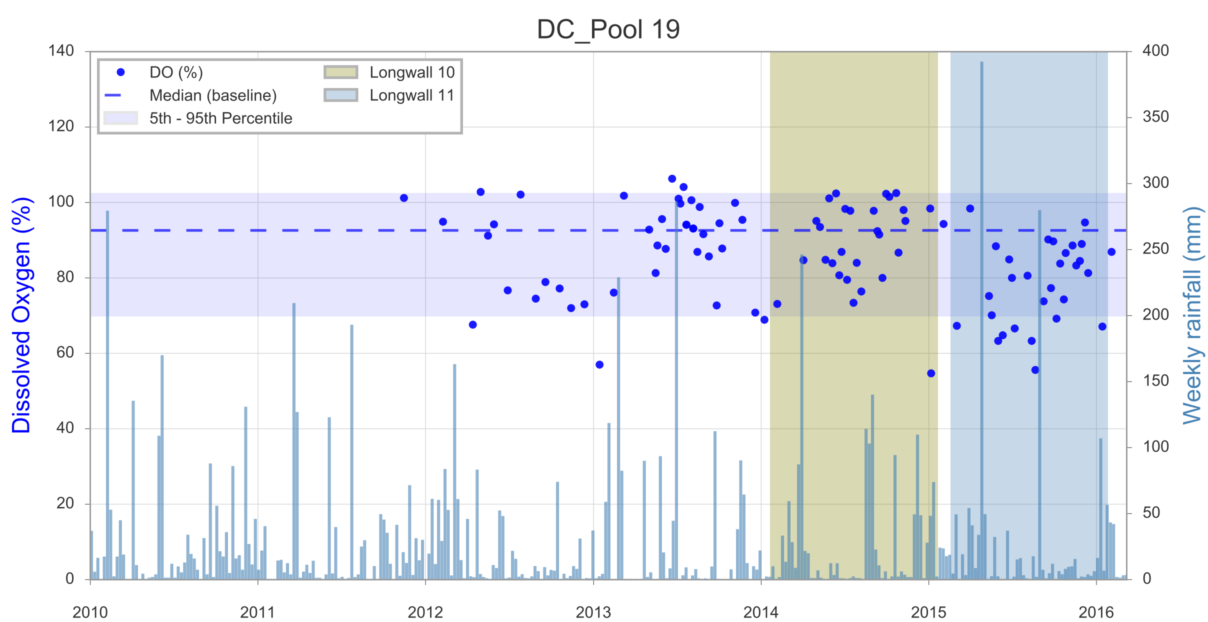
2014
2015
2016



DC_Pool 19
DO (%)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Dissolved Oxygen (%)
Weekly rainfall (mm)
0
20
40
60
80
100
120
140
0
50
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2010
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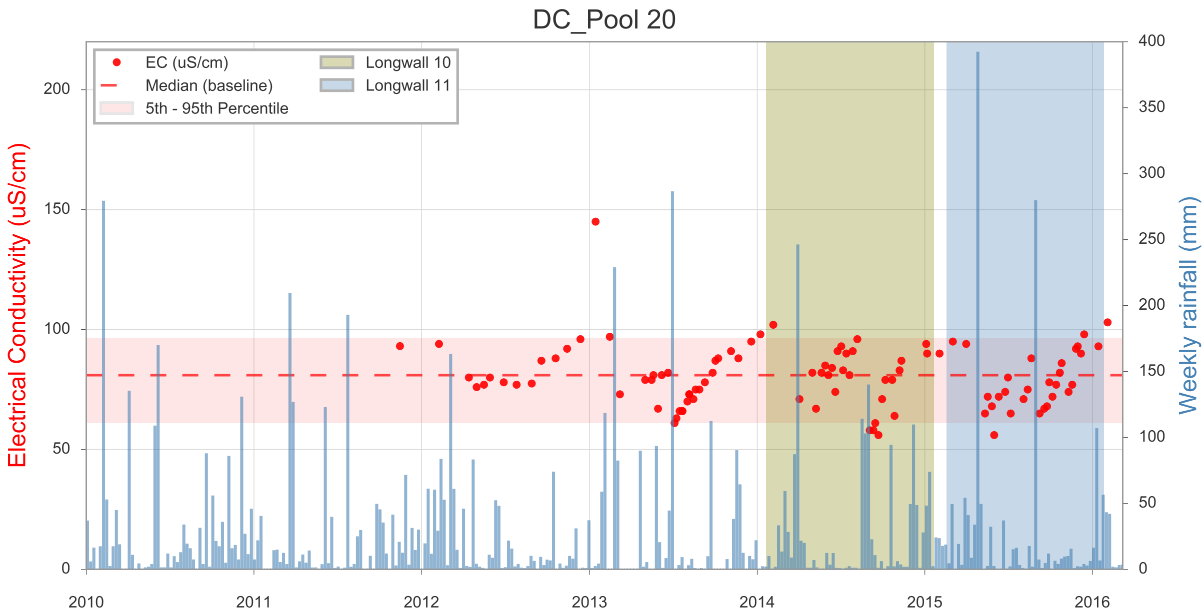
DC_Pool 20
EC (uS/cm)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Electrical Conductivity (uS/cm)
Weekly rainfall (mm)
0
50
100
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50
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2010
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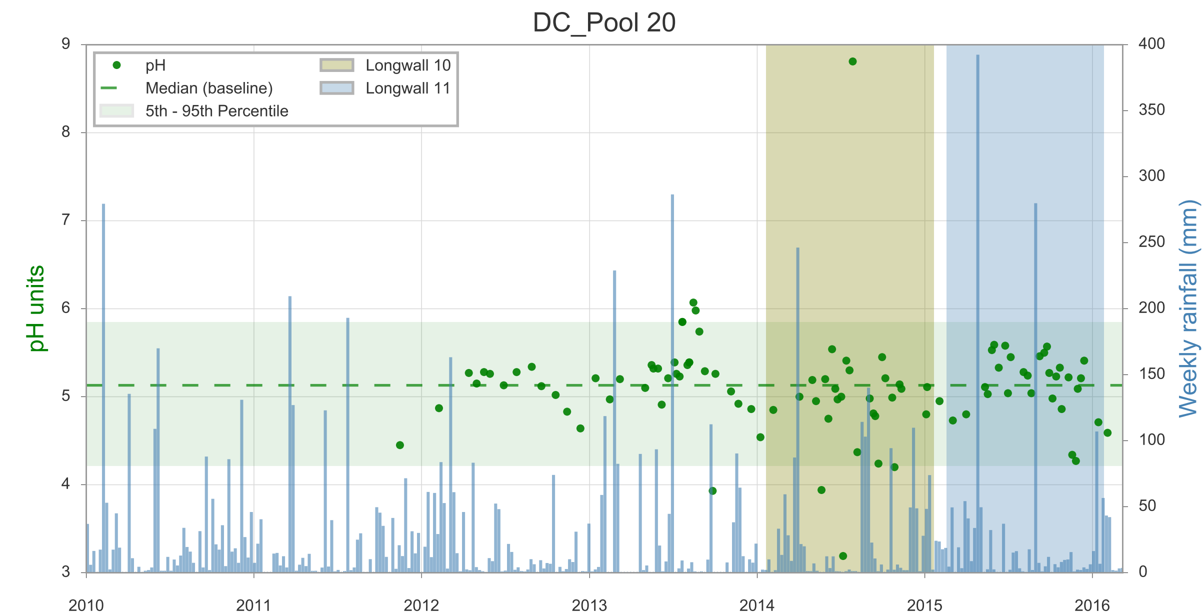
2016


DC_Pool 20
pH
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
pH units
Weekly rainfall (mm)
3
4
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2010
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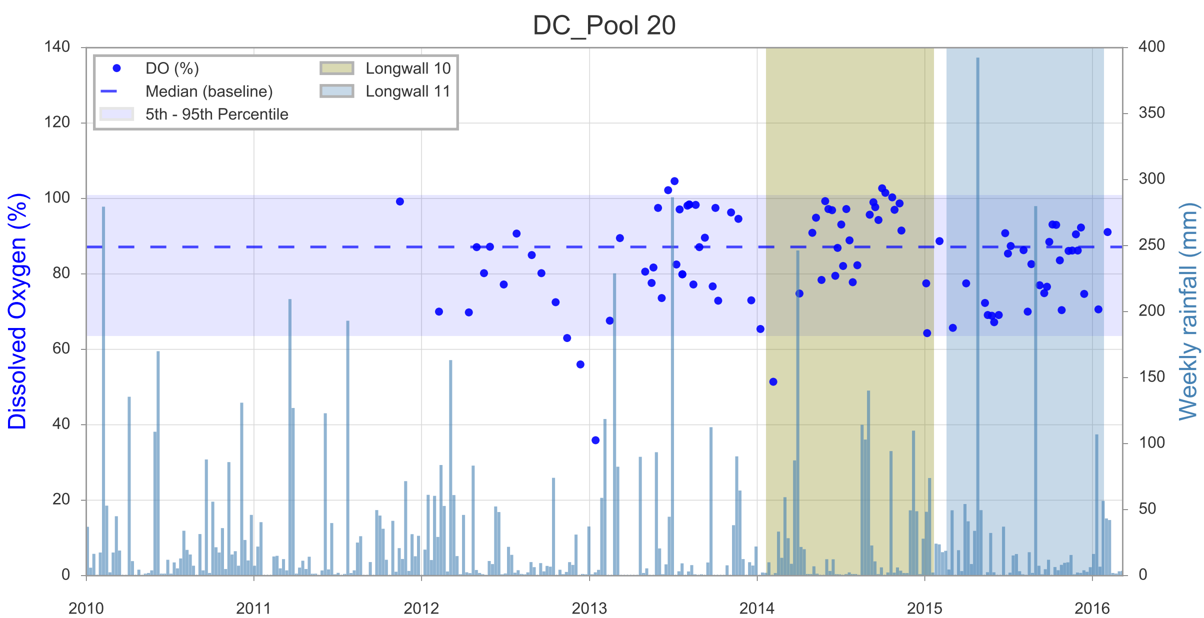
DC_Pool 20
DO (%)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Dissolved Oxygen (%)
Weekly rainfall (mm)
0
20
40
60
80
100
120
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0
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100
150
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250
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2010
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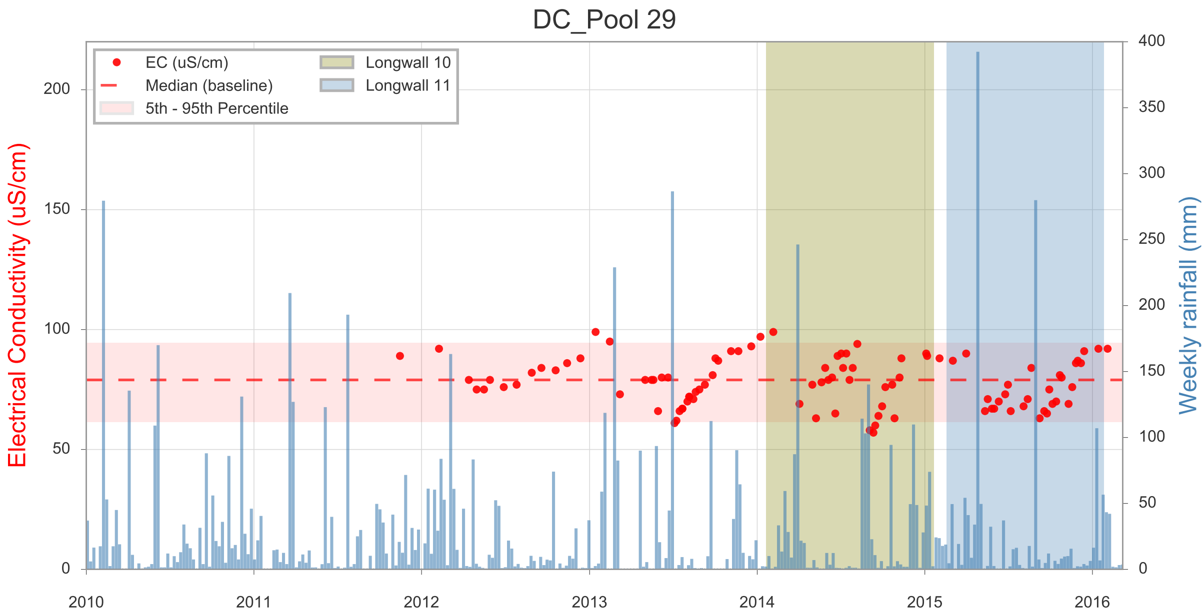
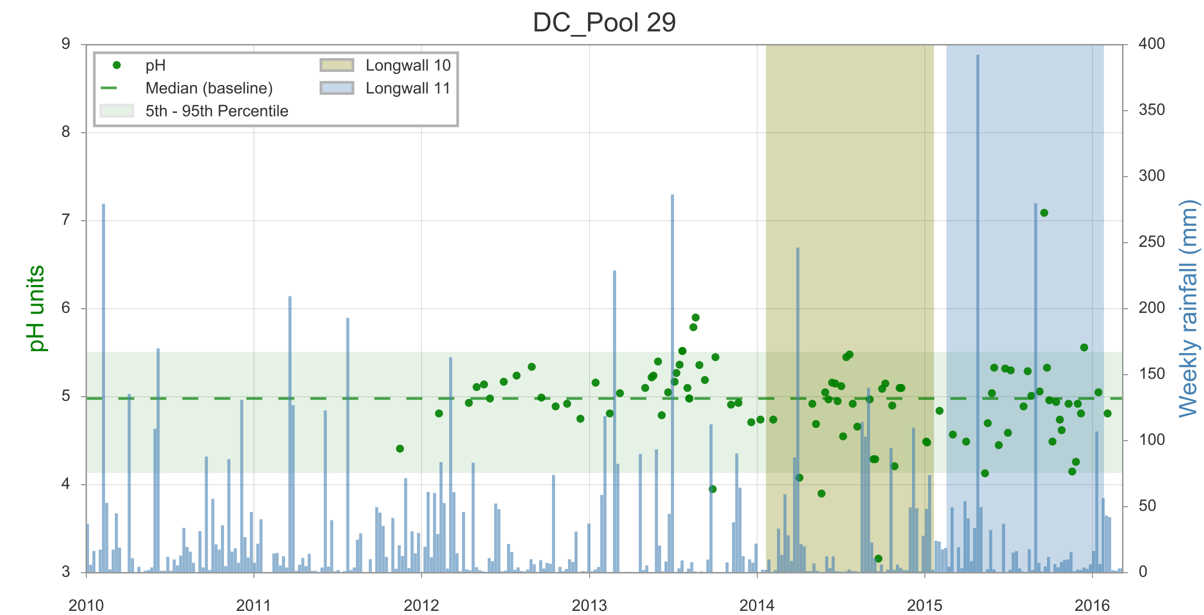
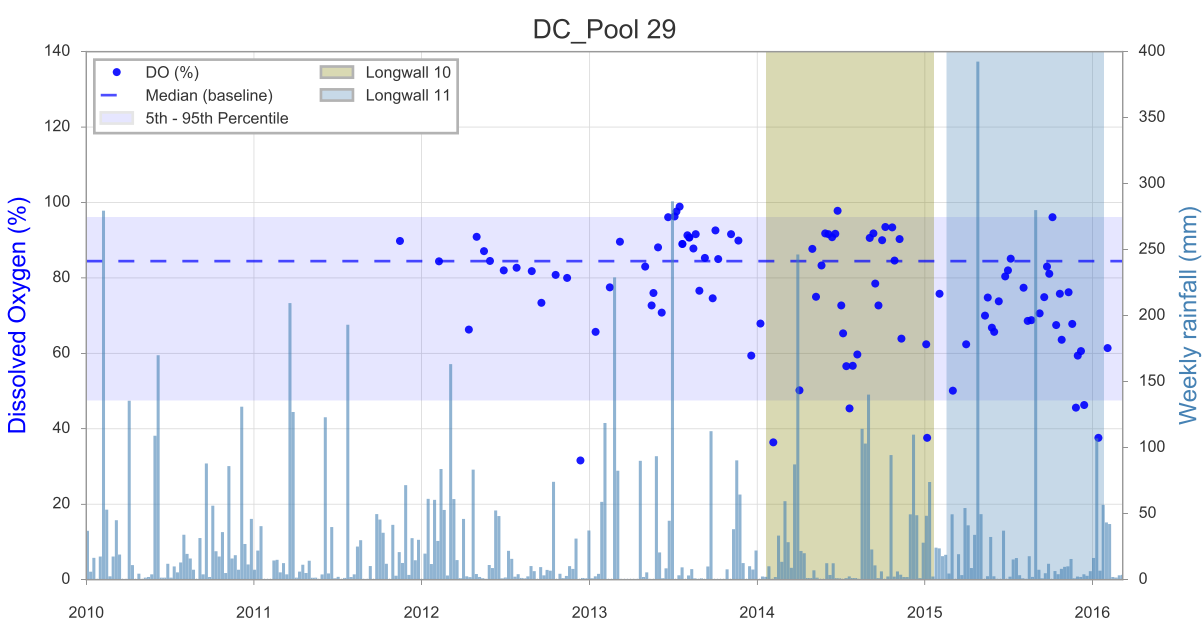


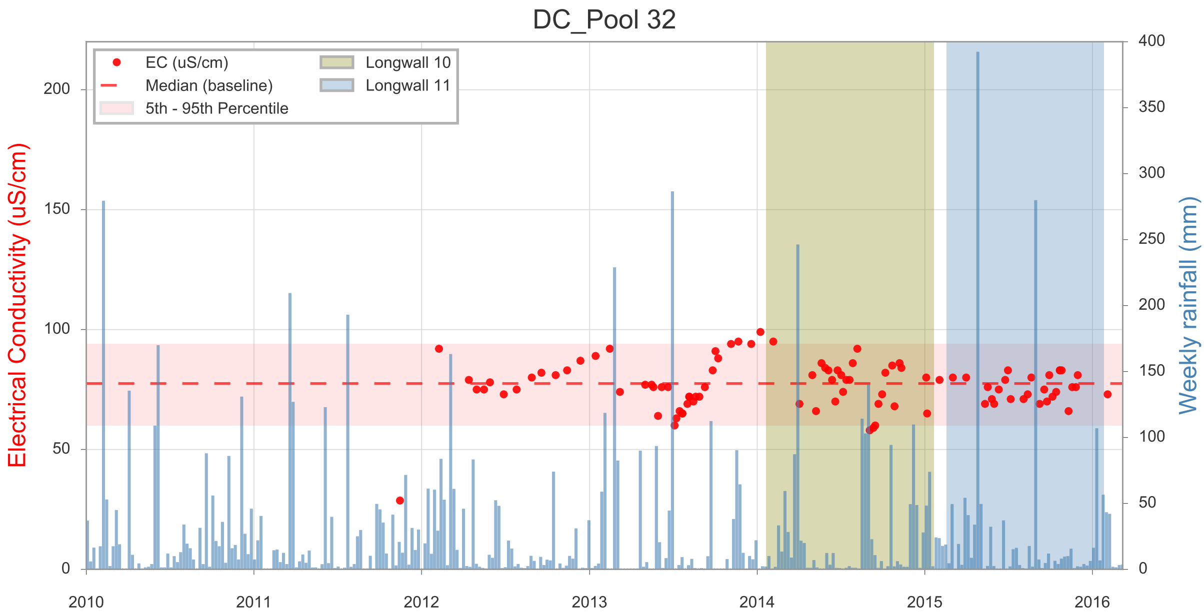
DC_Pool 29
EC (uS/cm)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Electrical Conductivity (uS/cm)
Weekly rainfall (mm)

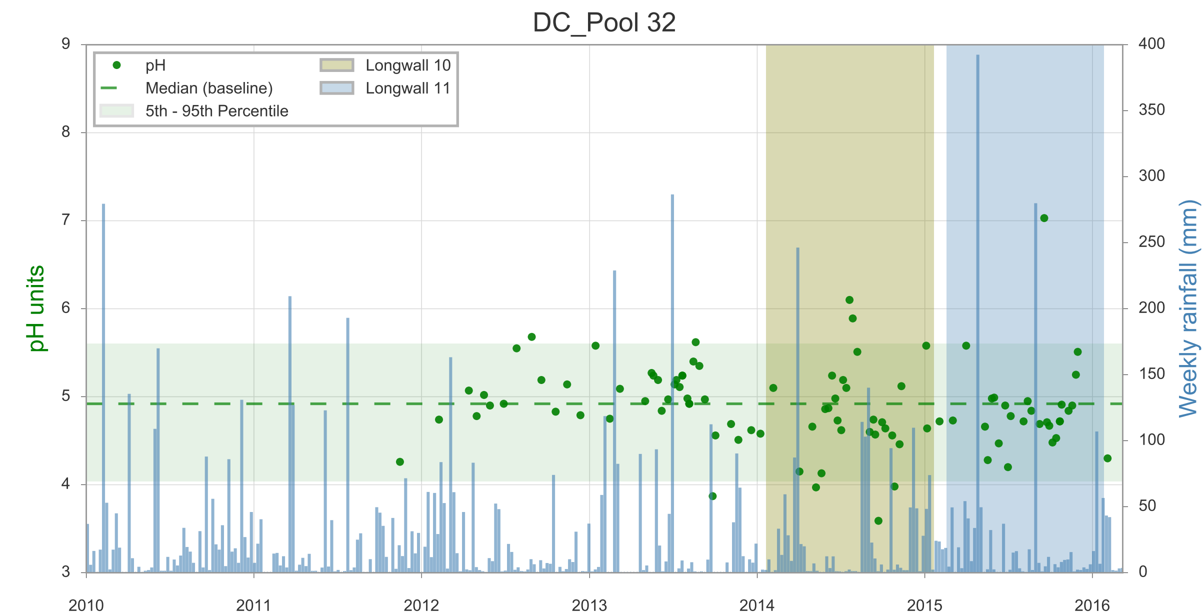


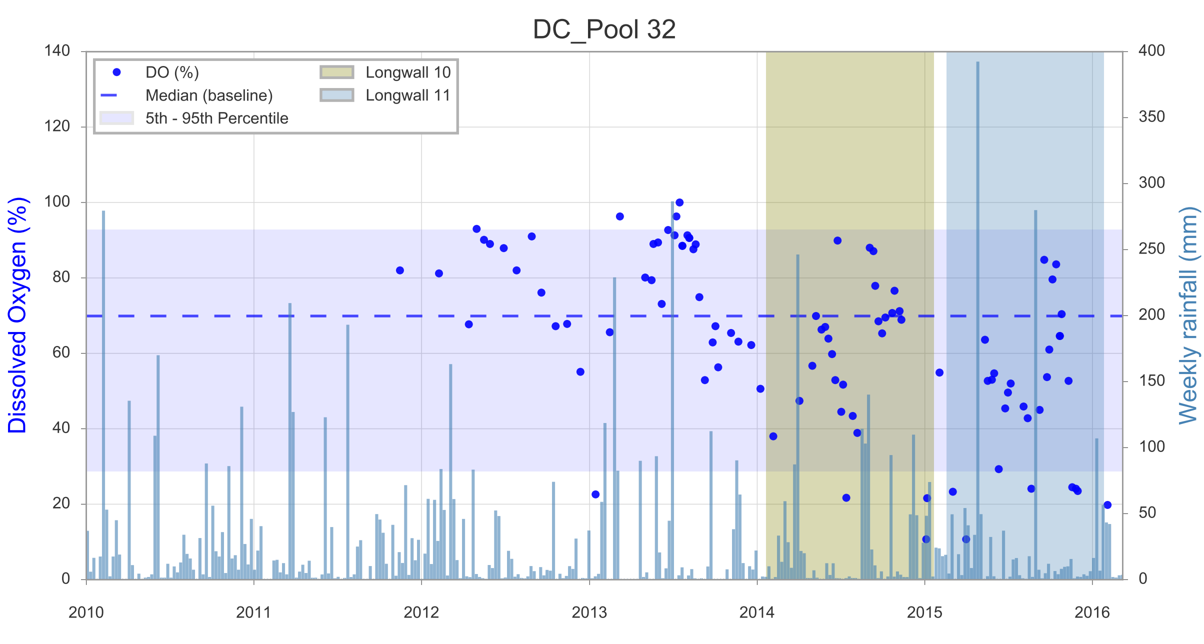
DC_Pool 29
pH
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
pH units
Weekly rainfall (mm)

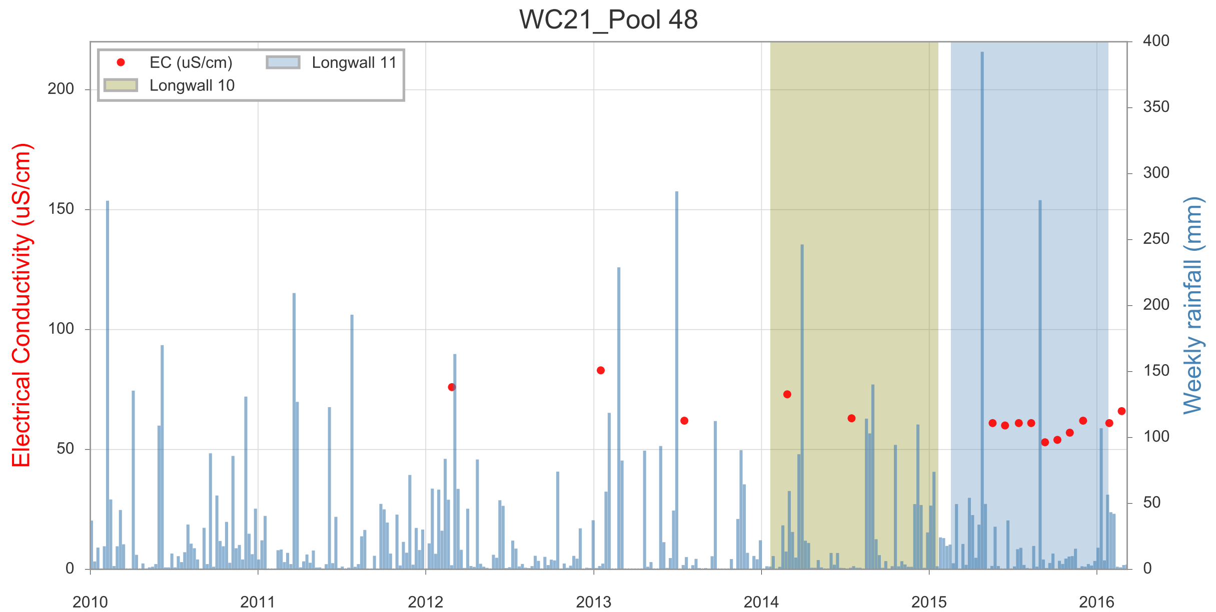


DC_Pool 29
DO (%)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Dissolved Oxygen (%)
Weekly rainfall (mm)

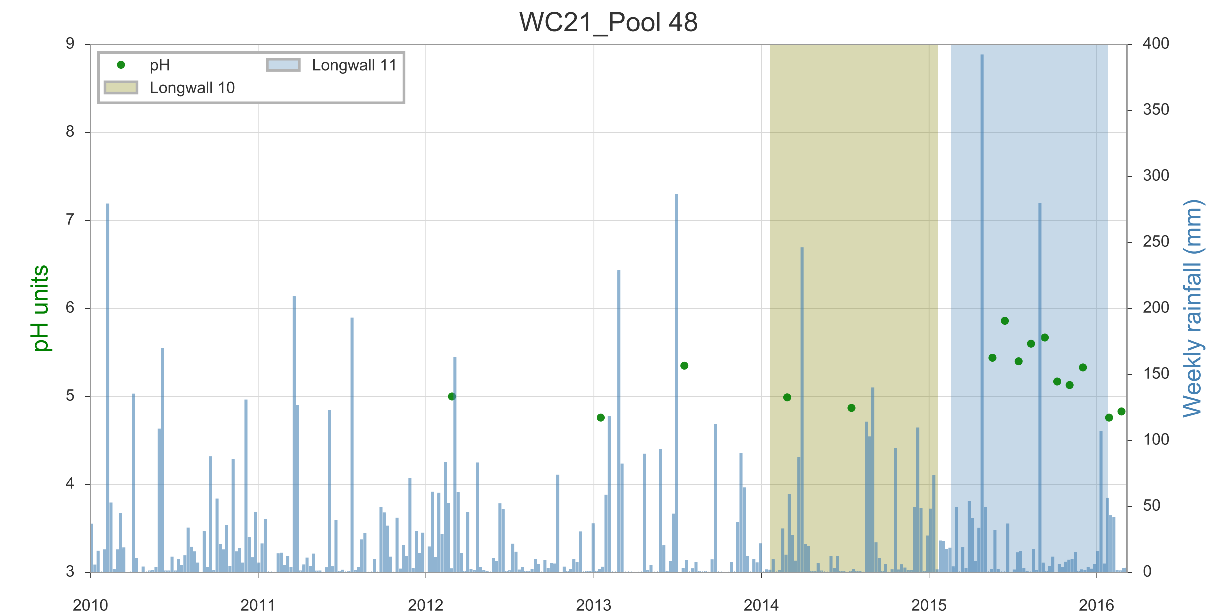

DC_Pool 32
EC (uS/cm)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Electrical Conductivity (uS/cm)
Weekly rainfall (mm)
0
50
100
150
200
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016


DC_Pool 32
pH
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
pH units
Weekly rainfall (mm)
3
4
5
6
7
8
9
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016

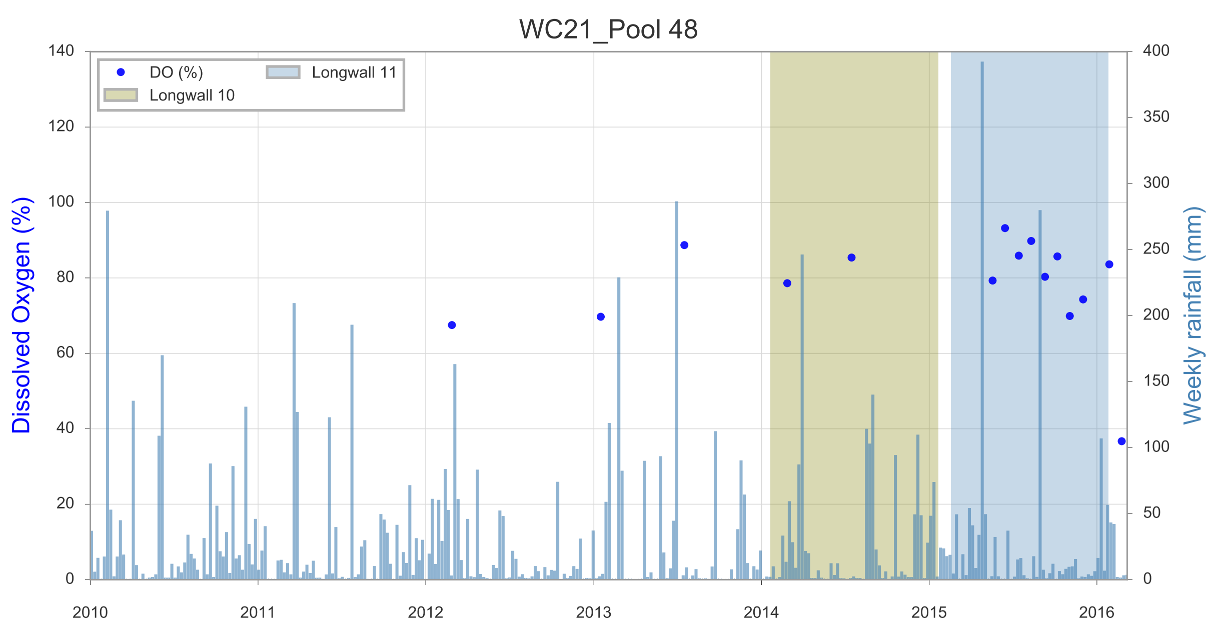

DC_Pool 32
DO (%)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Dissolved Oxygen (%)
Weekly rainfall (mm)
0
20
40
60
80
100
120
140
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016



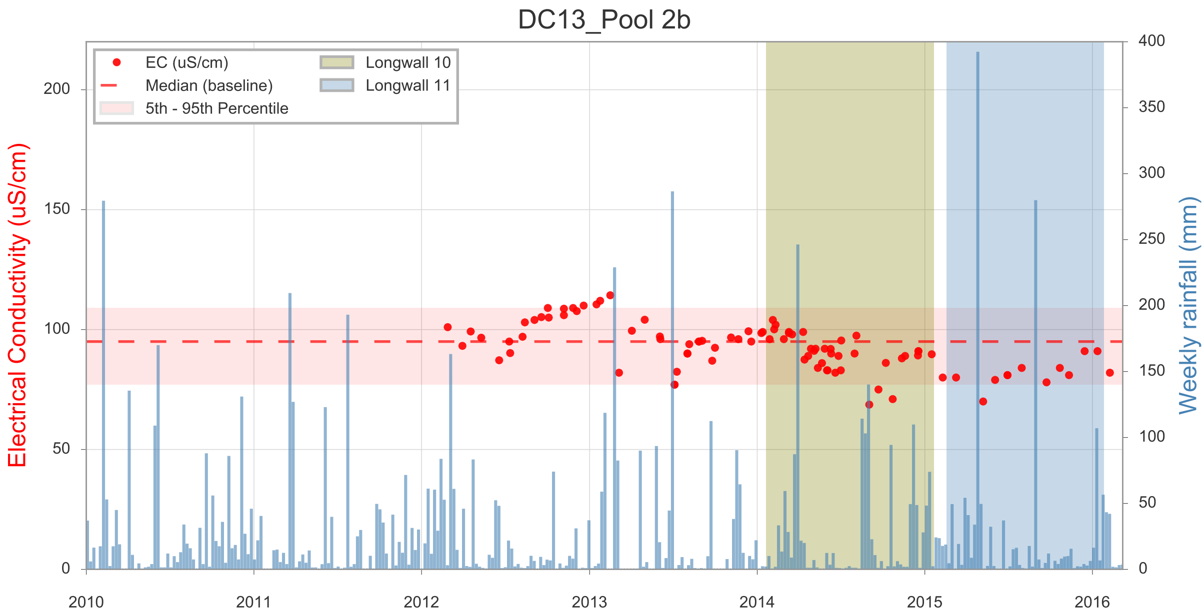
WC21_Pool 48
EC (uS/cm)
Longwall 10
Longwall 11
Electrical Conductivity (uS/cm)
Weekly rainfall (mm)
0
50
100
150
200
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016

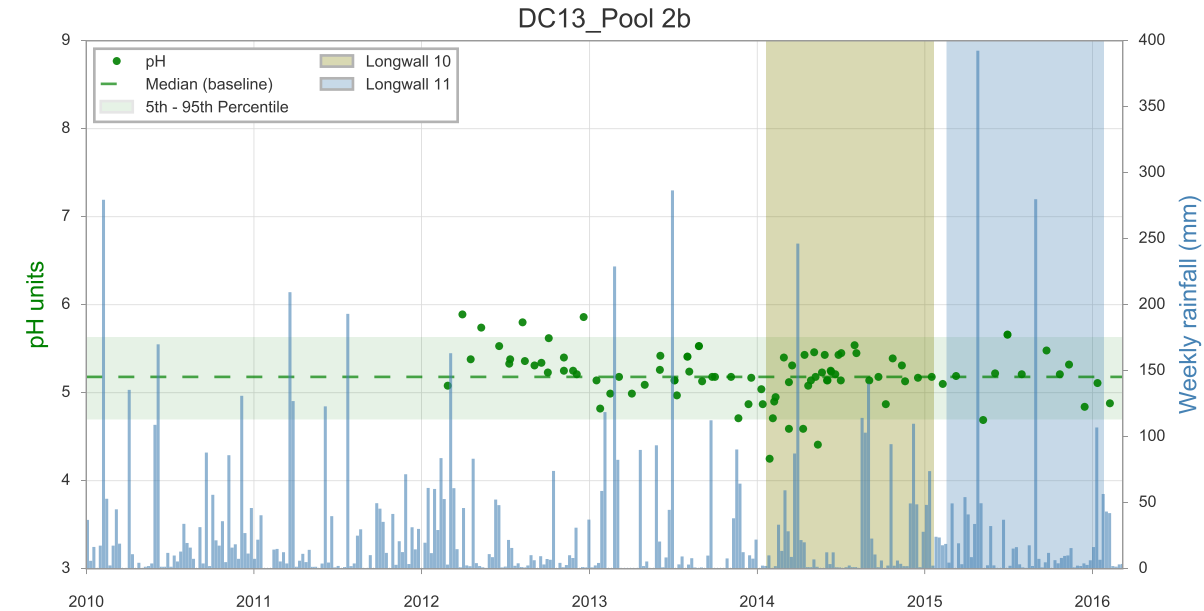


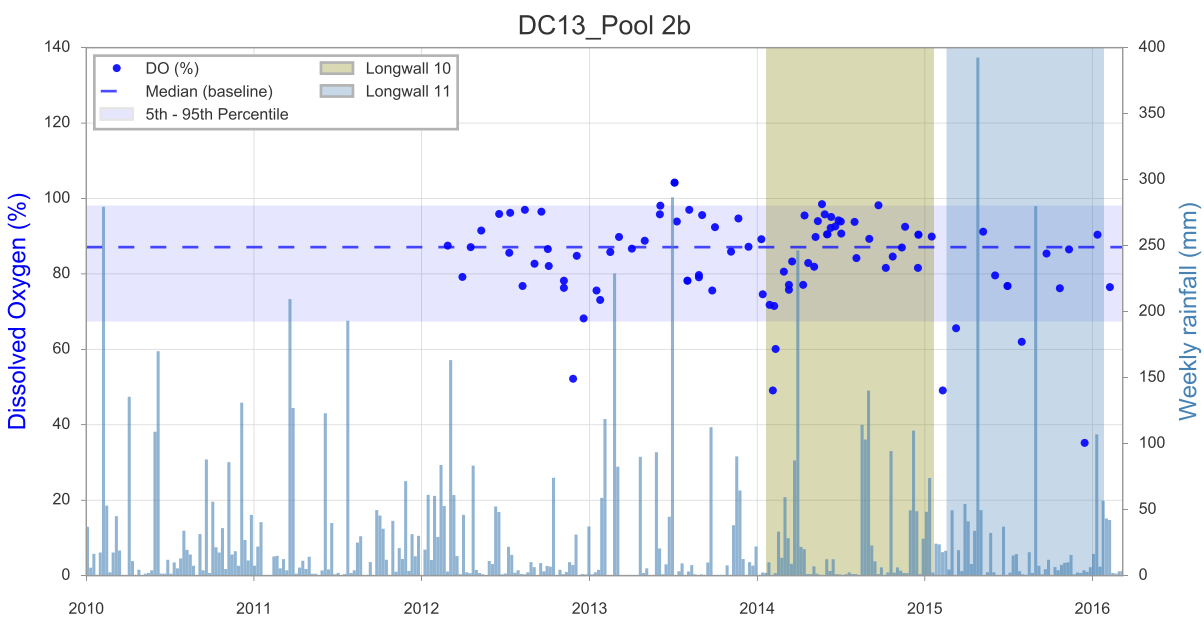
WC21_Pool 48
pH
Longwall 10
Longwall 11
pH units
Weekly rainfall (mm)
3
4
5
6
7
8
9
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016

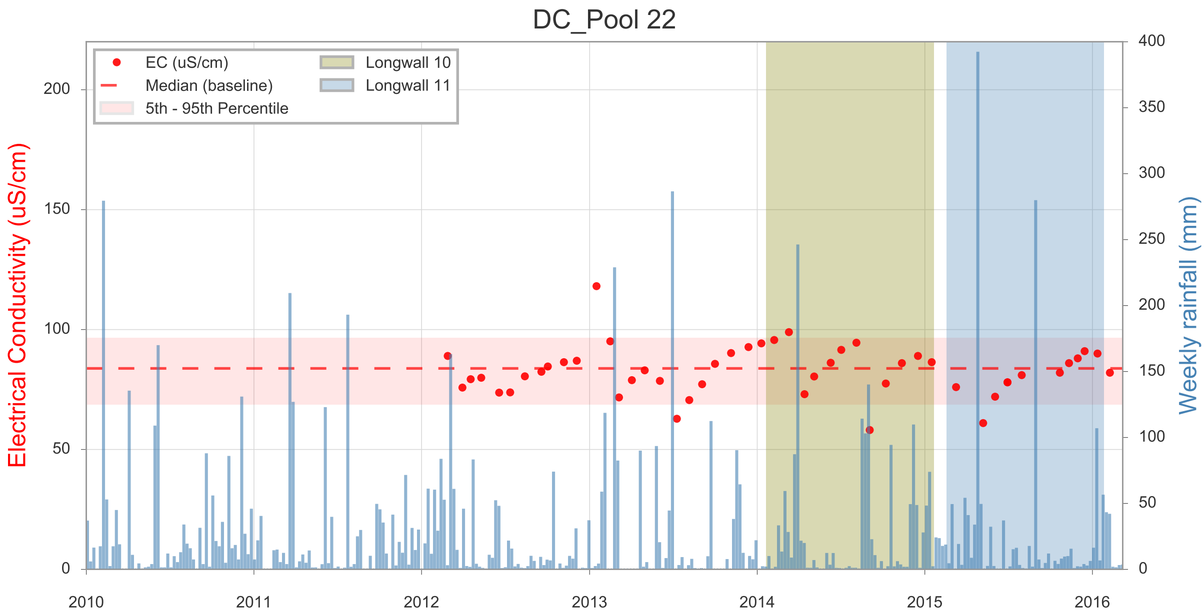


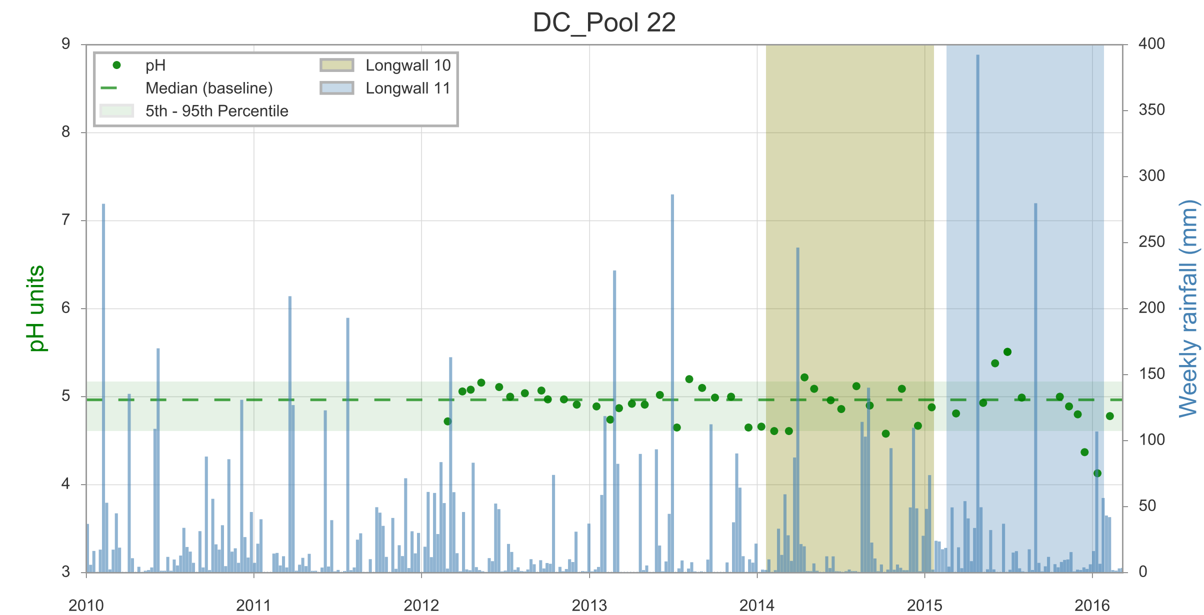
WC21_Pool 48
DO (%)
Longwall 10
Longwall 11
Dissolved Oxygen (%)
Weekly rainfall (mm)
0
20
40
60
80
100
120
140
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016

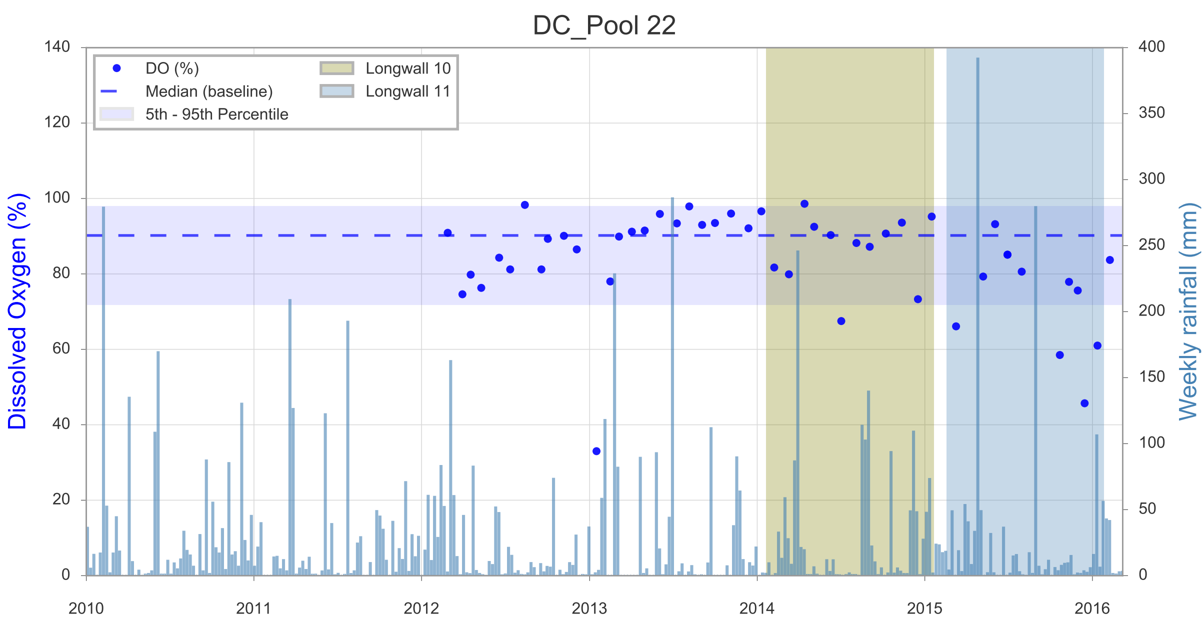

DC13_Pool 2b
EC (uS/cm)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Electrical Conductivity (uS/cm)
Weekly rainfall (mm)
0
50
100
150
200
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016

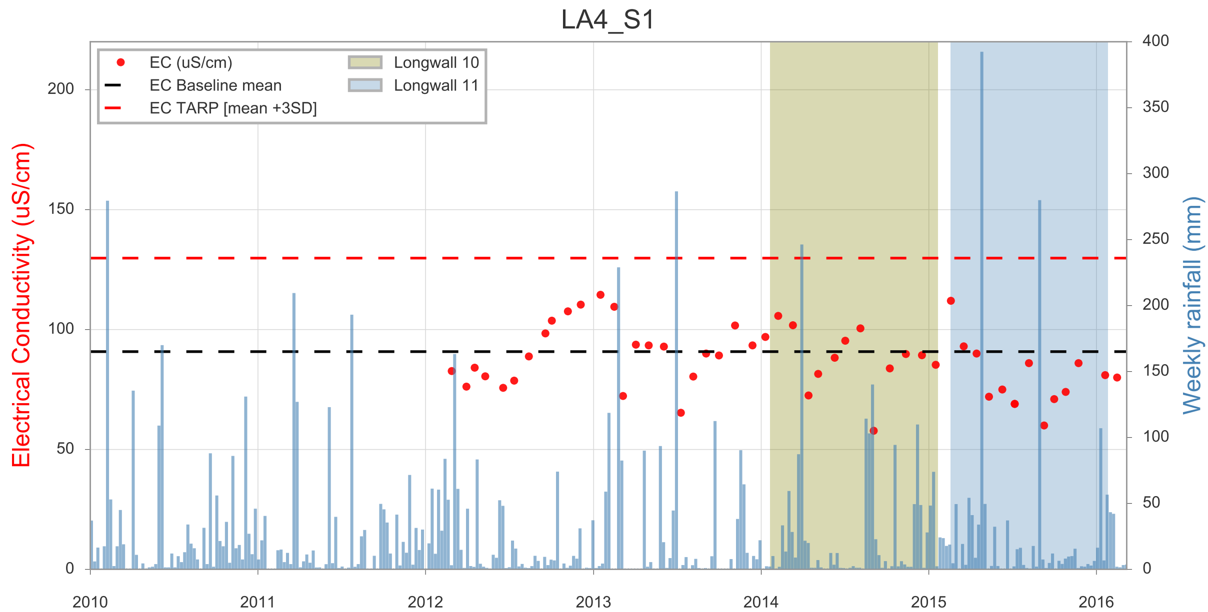

DC13_Pool 2b
pH
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
pH units
Weekly rainfall (mm)
3
4
5
6
7
8
9
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016


DC13_Pool 2b
DO (%)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Dissolved Oxygen (%)
Weekly rainfall (mm)
0
20
40
60
80
100
120
140
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016

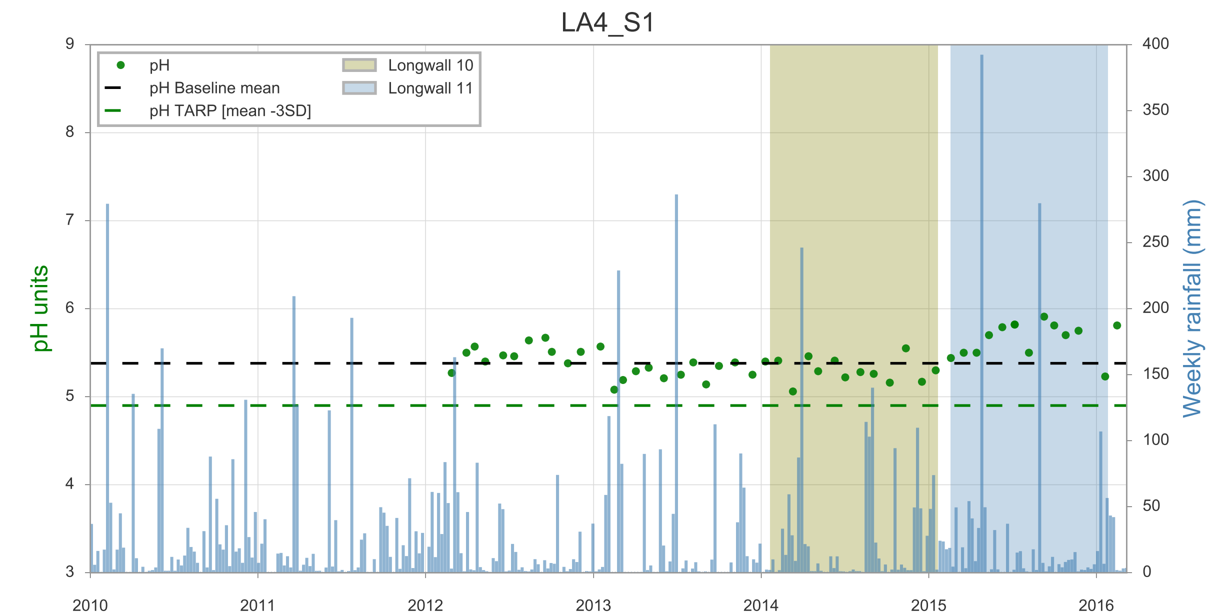

DC_Pool 22
EC (uS/cm)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Electrical Conductivity (uS/cm)
Weekly rainfall (mm)
2010
2011
2012
2013
2014
2015
2016


DC_Pool 22
pH
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
pH units
Weekly rainfall (mm)
2010
2011
2012
2013
2014
2015
2016

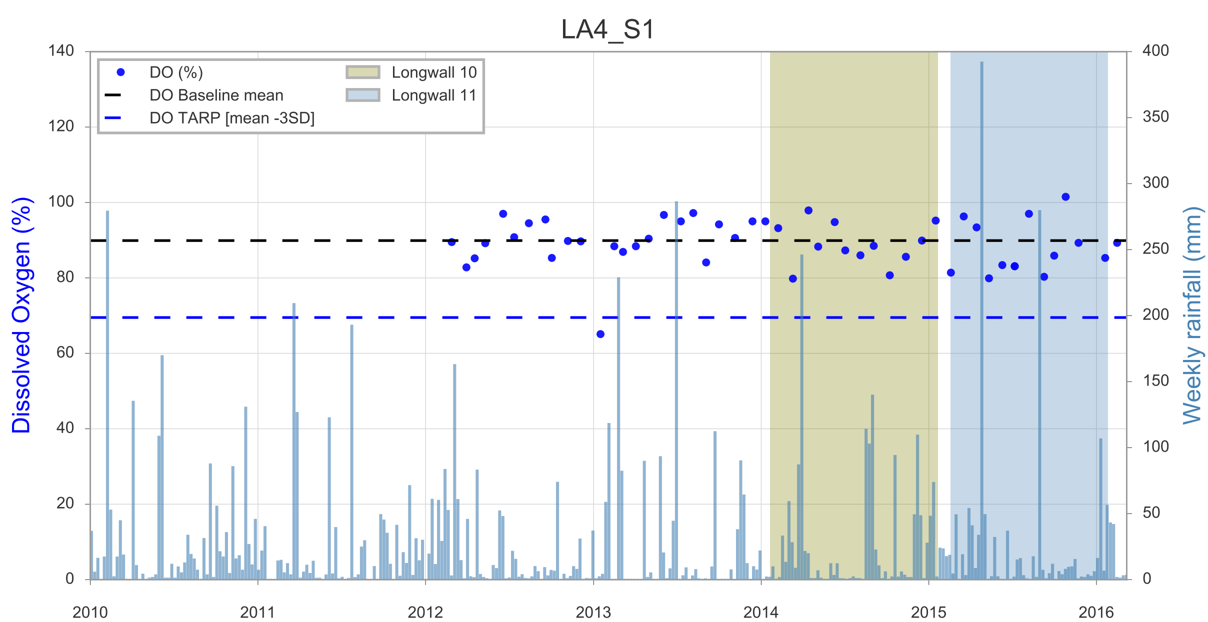

DC_Pool 22
DO (%)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Dissolved Oxygen (%)
Weekly rainfall (mm)
2010
2011
2012
2013
2014
2015
2016



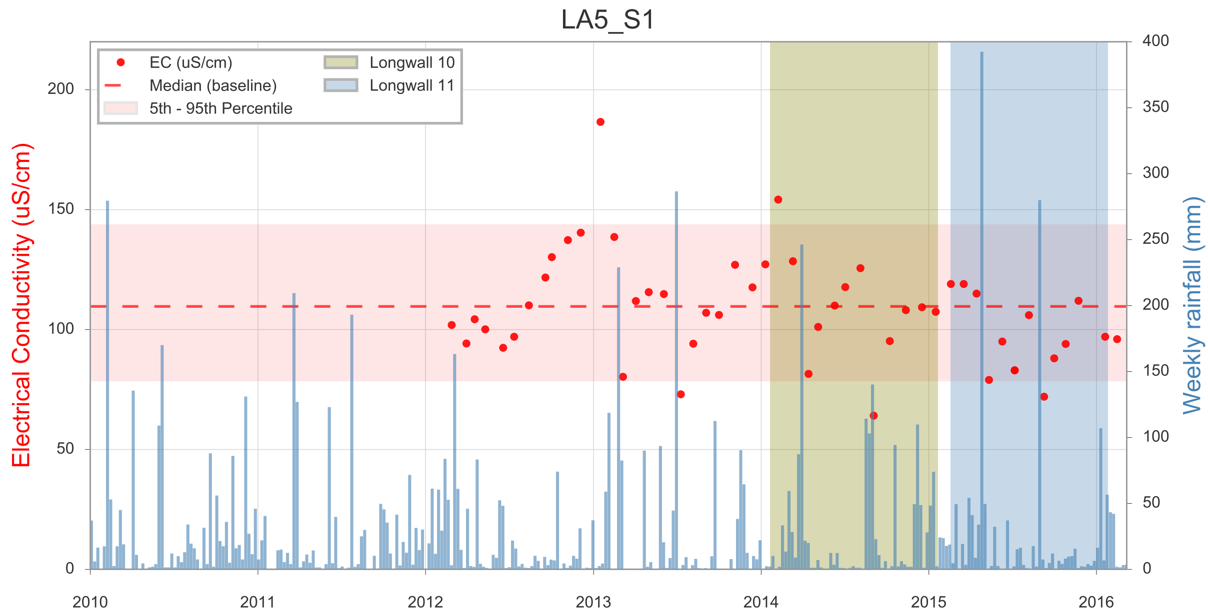
LA4_S1
EC (uS/cm)
EC Baseline mean
EC TARP [mean +3SD]
Longwall 10
Longwall 11
Electrical Conductivity (uS/cm)
Weekly rainfall (mm)

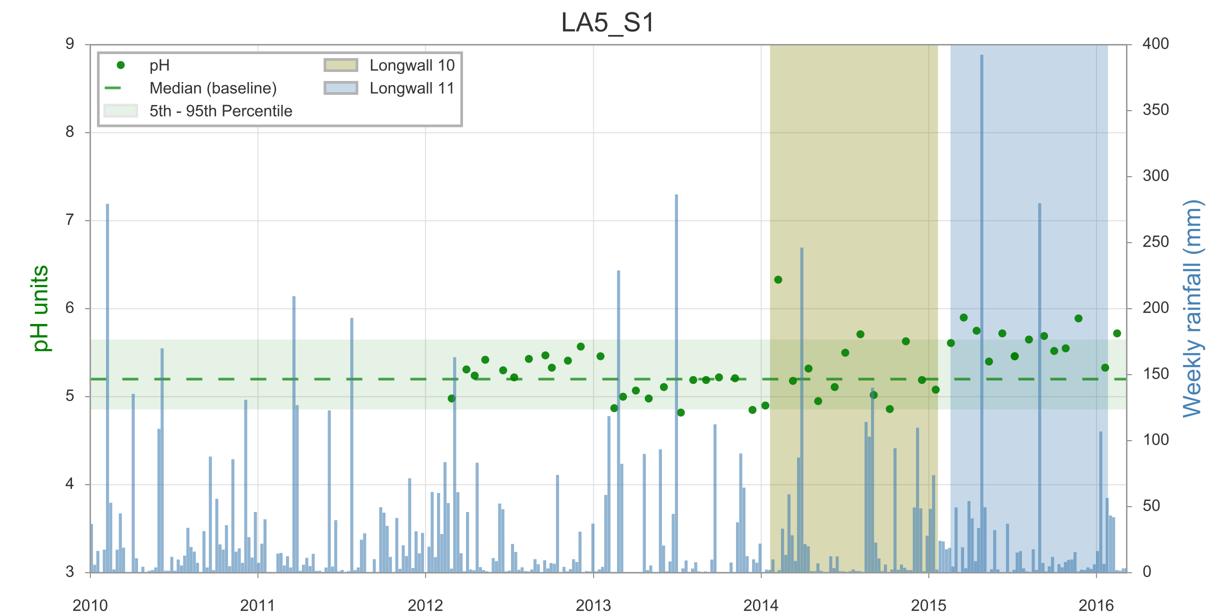


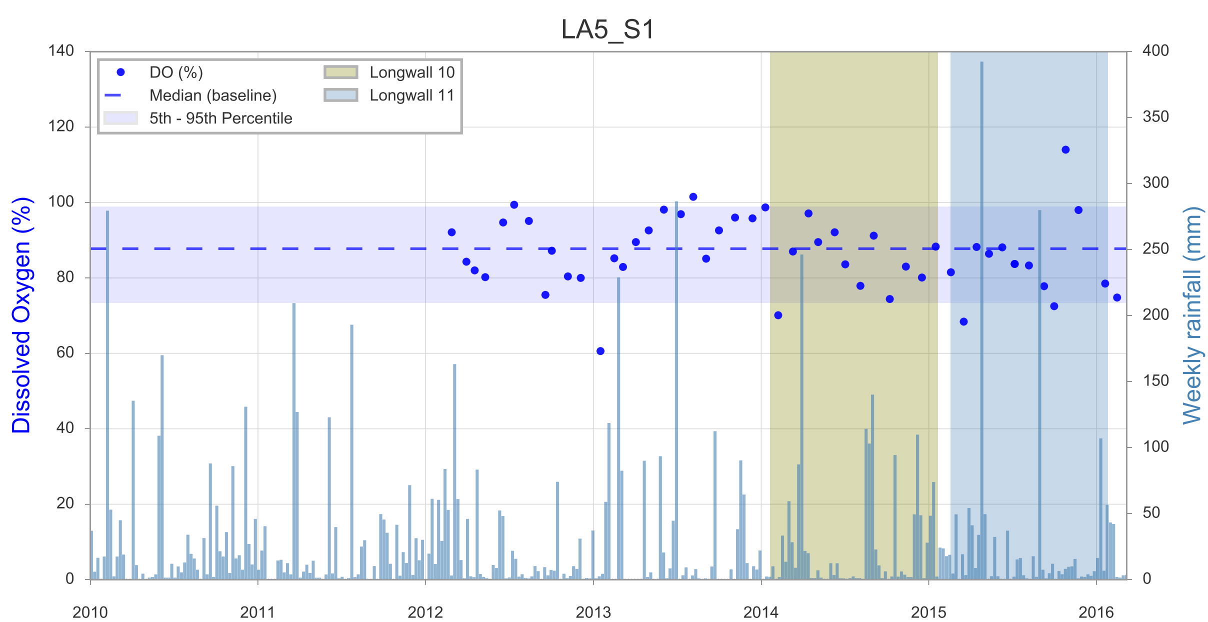
LA4_S1
pH
pH Baseline mean
pH TARP [mean -3SD]
Longwall 10
Longwall 11
pH units
Weekly rainfall (mm)

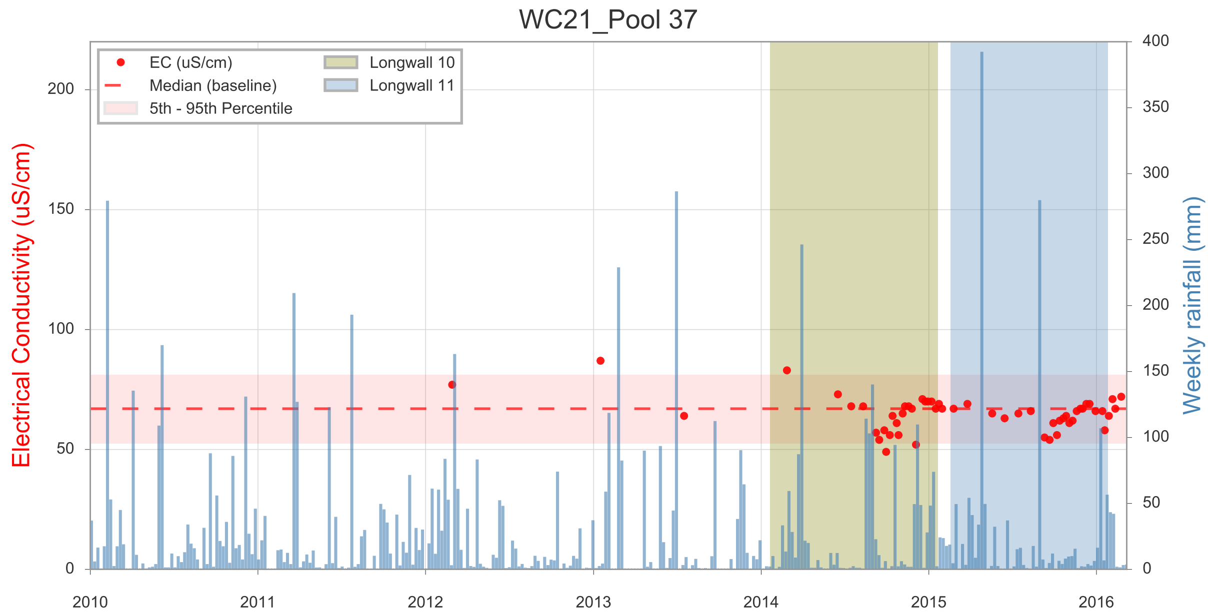


LA4_S1
DO (%)
DO Baseline mean
DO TARP [mean -3SD]
Longwall 10
Longwall 11
Dissolved Oxygen (%)
Weekly rainfall (mm)

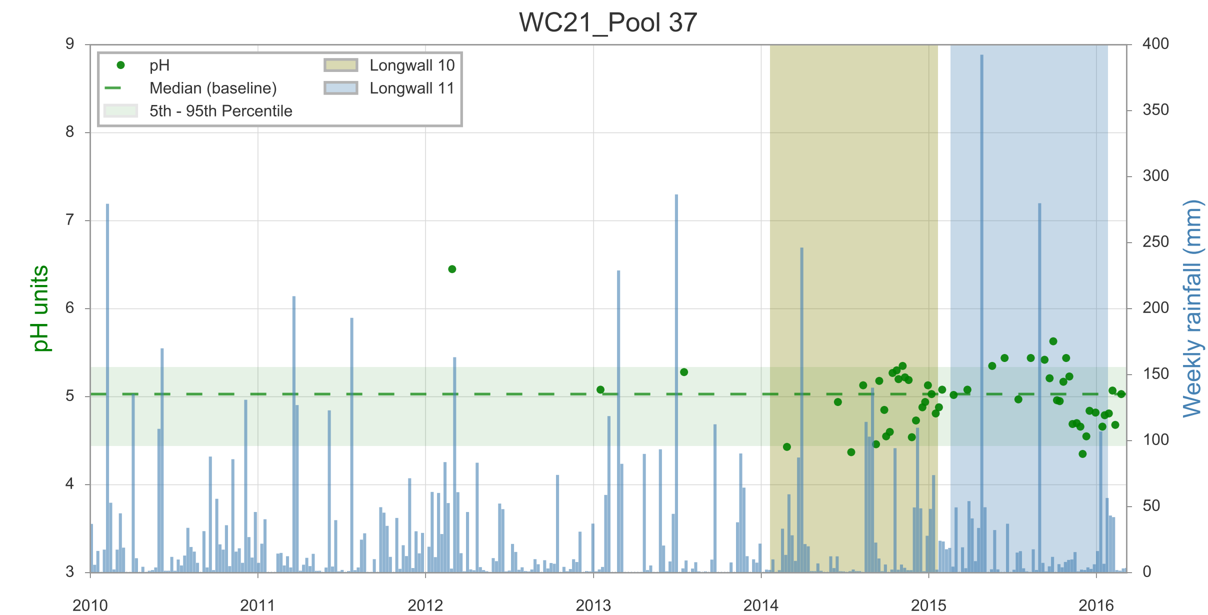

LA5_S1
EC (uS/cm)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Electrical Conductivity (uS/cm)
Weekly rainfall (mm)
0
50
100
150
200
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016


LA5_S1
pH
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
pH units
Weekly rainfall (mm)
3
4
5
6
7
8
9
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016

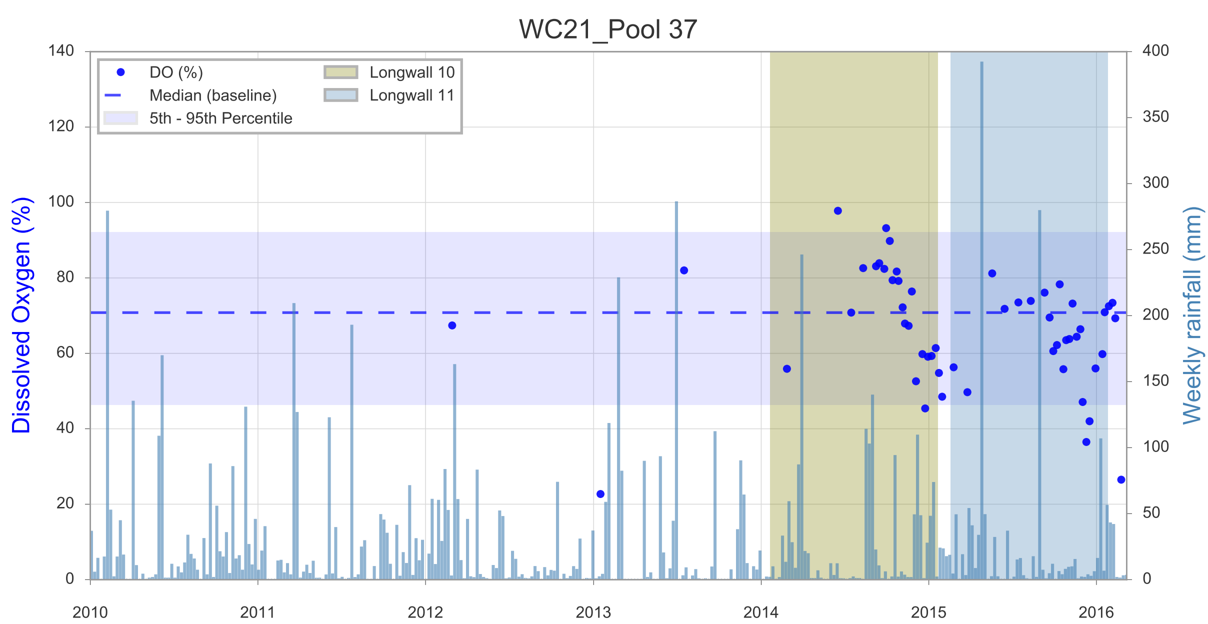

LA5_S1
DO (%)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Dissolved Oxygen (%)
Weekly rainfall (mm)
0
20
40
60
80
100
120
140
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016



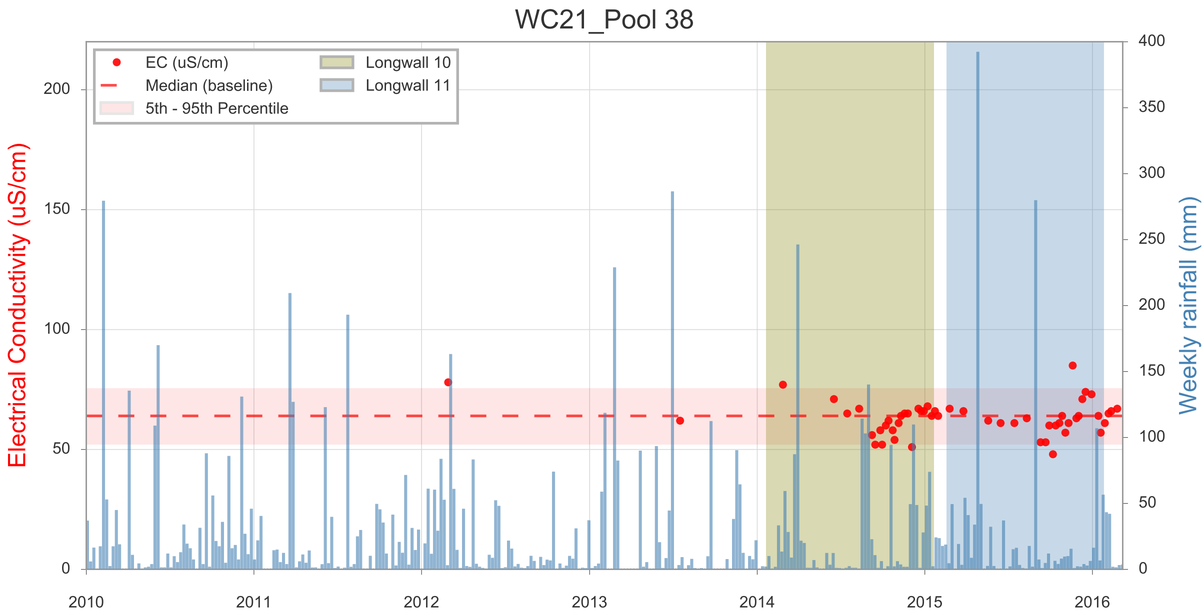
WC21_Pool 37
EC (uS/cm)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Electrical Conductivity (uS/cm)
Weekly rainfall (mm)
0
50
100
150
200
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016

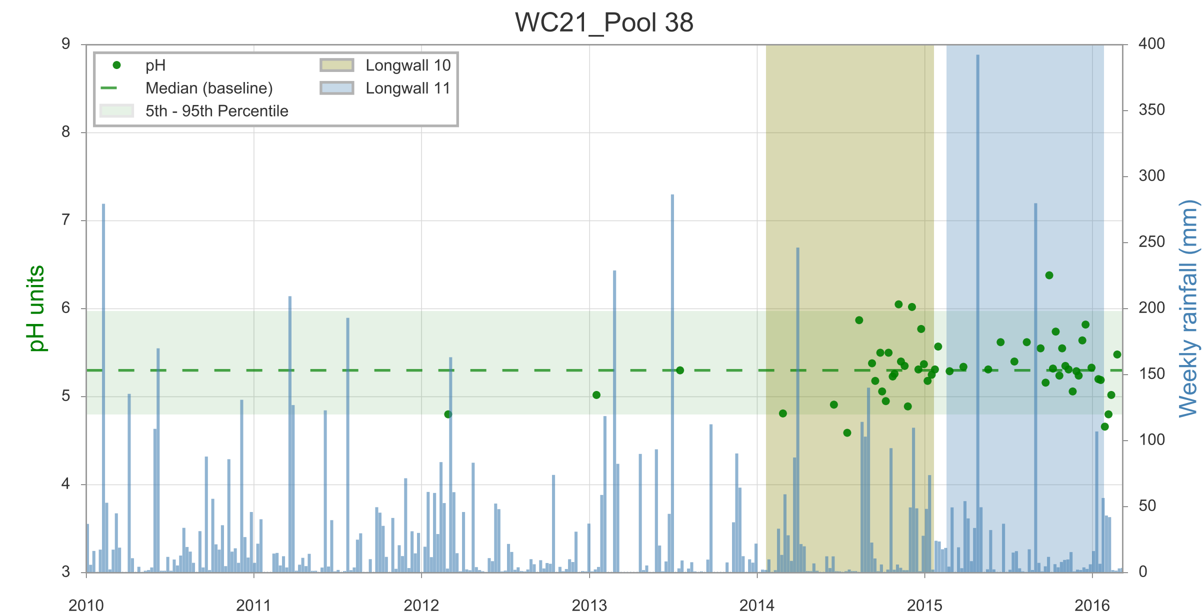


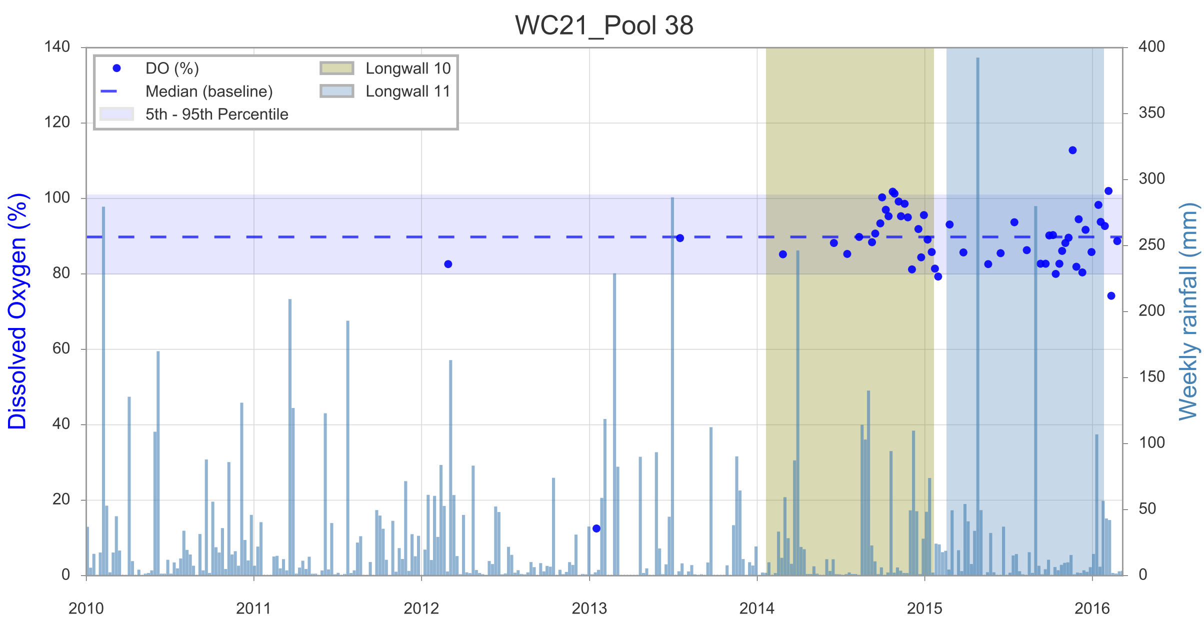
WC21_Pool 37
pH
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
pH units
Weekly rainfall (mm)
3
4
5
6
7
8
9
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016

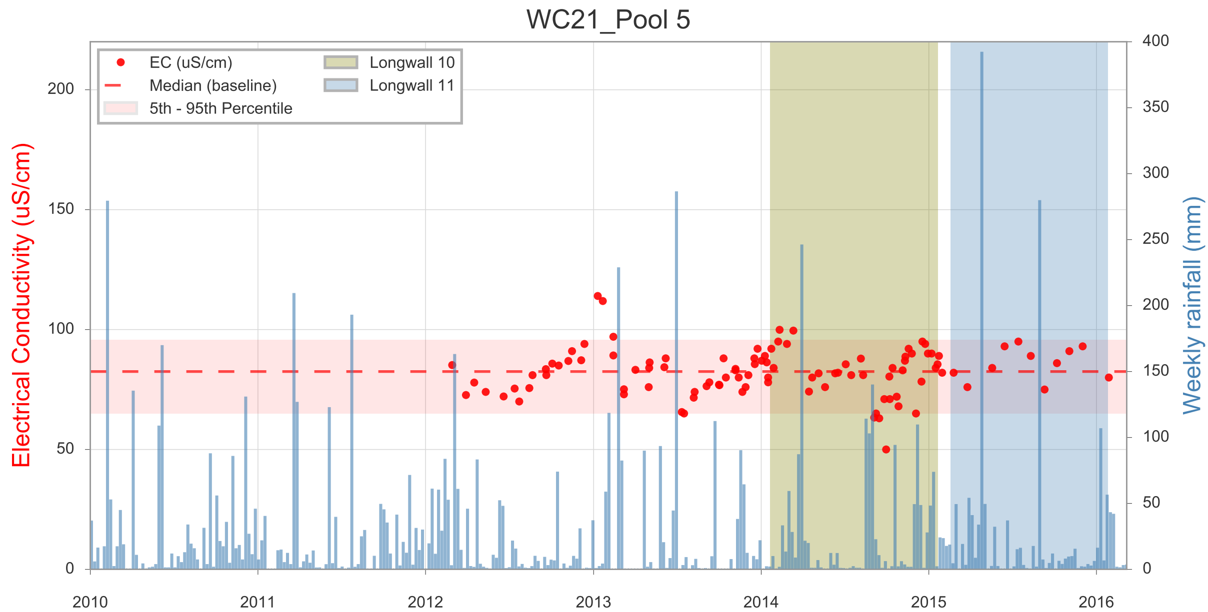


WC21_Pool 37
DO (%)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Dissolved Oxygen (%)
Weekly rainfall (mm)
0
20
40
60
80
100
120
140
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016

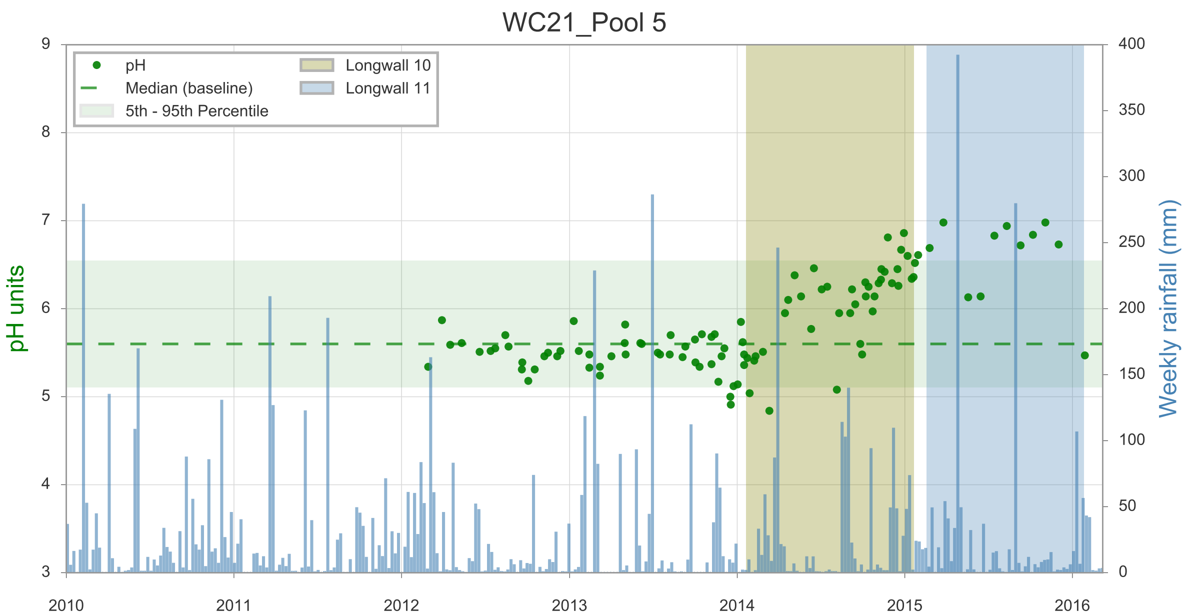

WC21_Pool 38
EC (uS/cm)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Electrical Conductivity (uS/cm)
Weekly rainfall (mm)
2010
2011
2012
2013
2014
2015
2016


WC21_Pool 38
pH
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
pH units
Weekly rainfall (mm)
2010
2011
2012
2013
2014
2015
2016

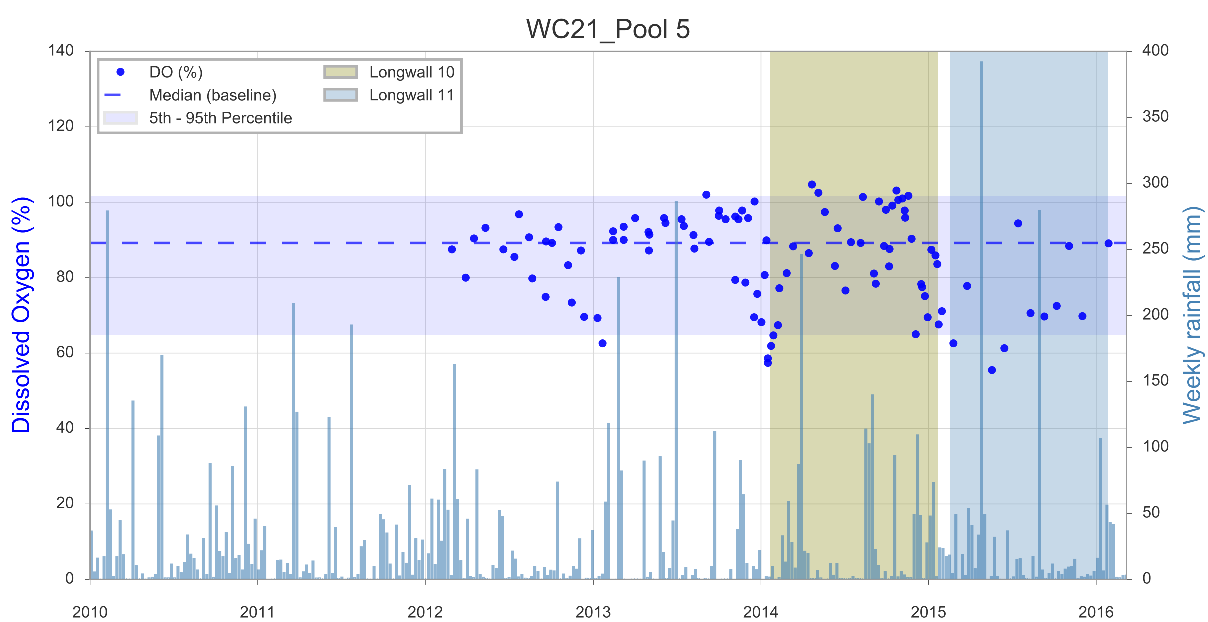

WC21_Pool 38
DO (%)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Dissolved Oxygen (%)
Weekly rainfall (mm)
2010
2011
2012
2013
2014
2015
2016



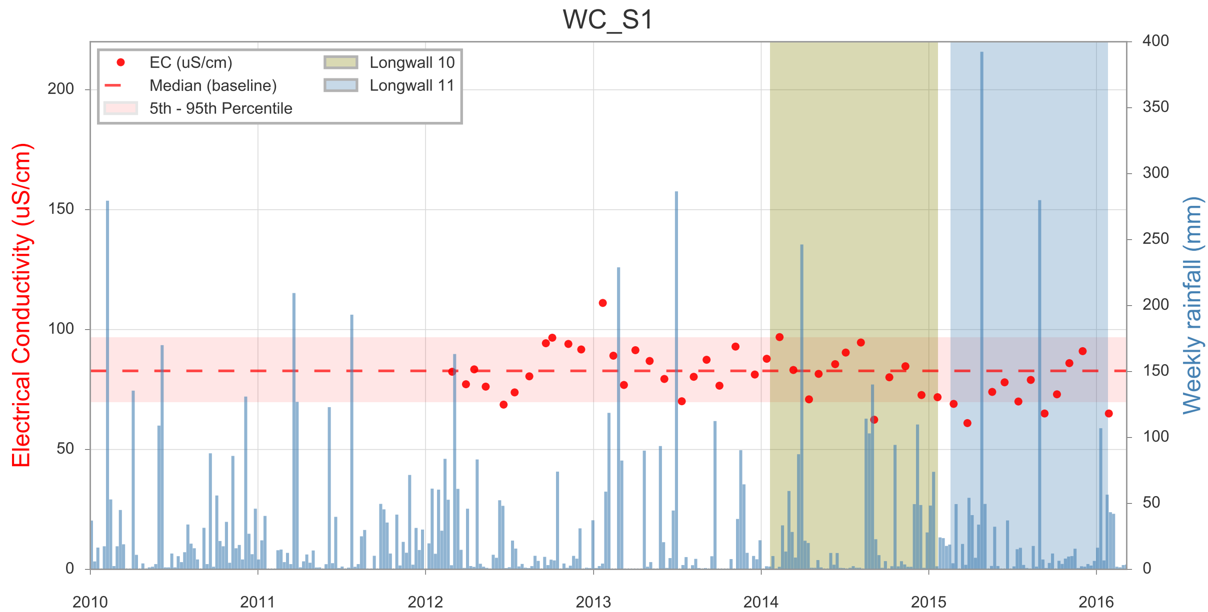
WC21_Pool 5
EC (uS/cm)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Electrical Conductivity (uS/cm)
Weekly rainfall (mm)
0
50
100
150
200
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016



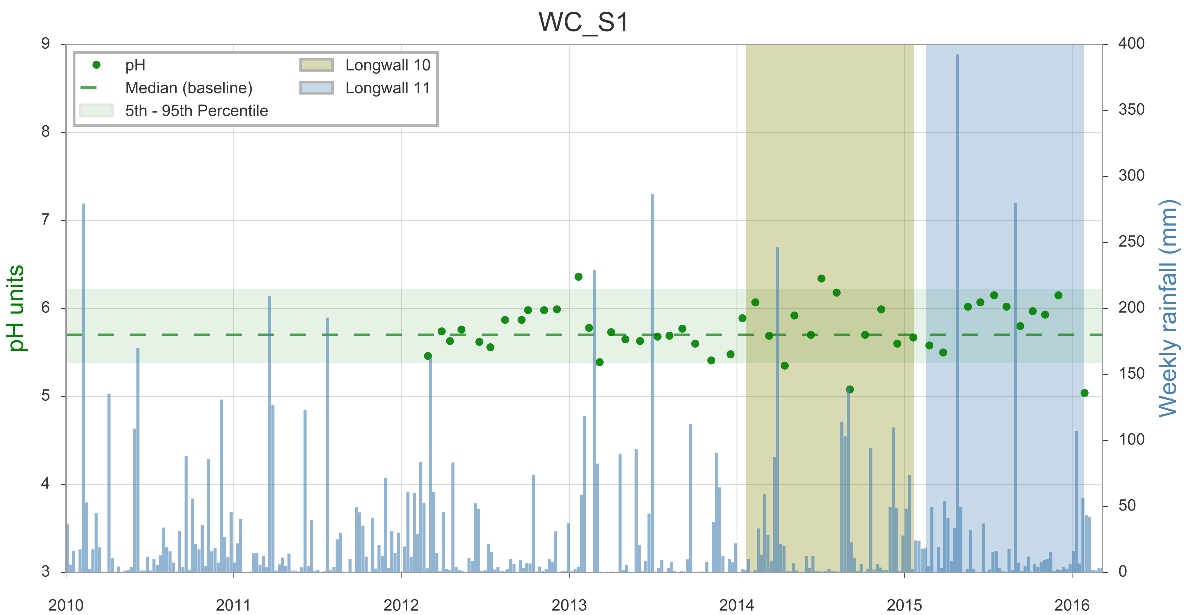
WC21_Pool 5
pH
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
pH units
Weekly rainfall (mm)
3
4
5
6
7
8
9
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016



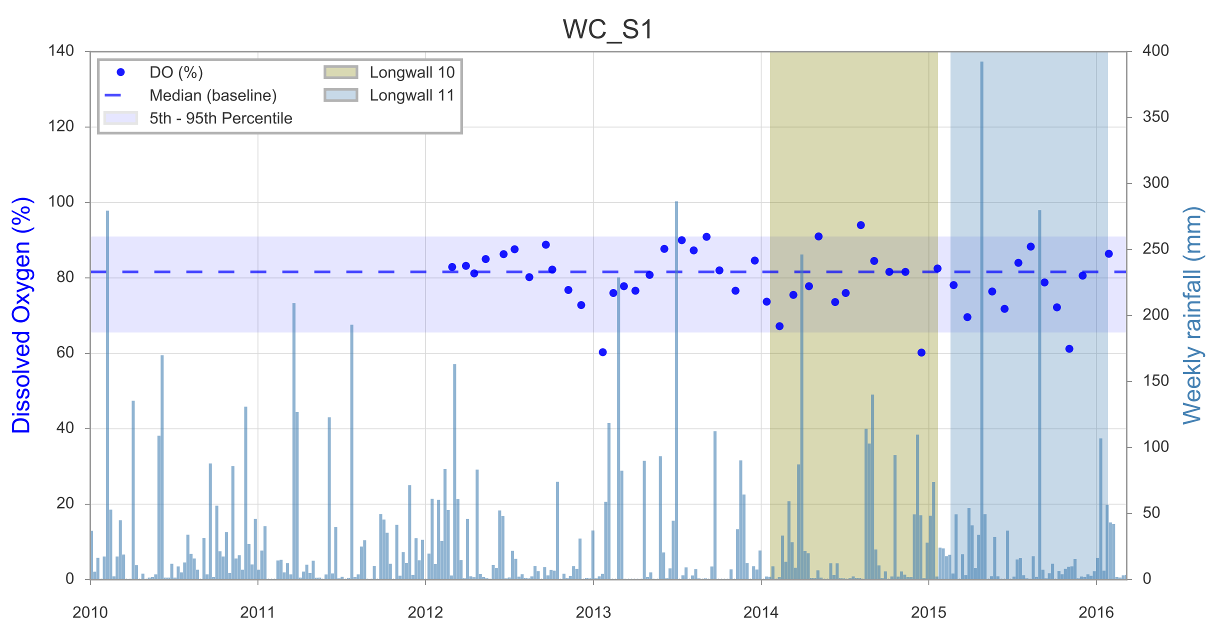
WC21_Pool 5
DO (%)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Dissolved Oxygen (%)
Weekly rainfall (mm)
0
20
40
60
80
100
120
140
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016



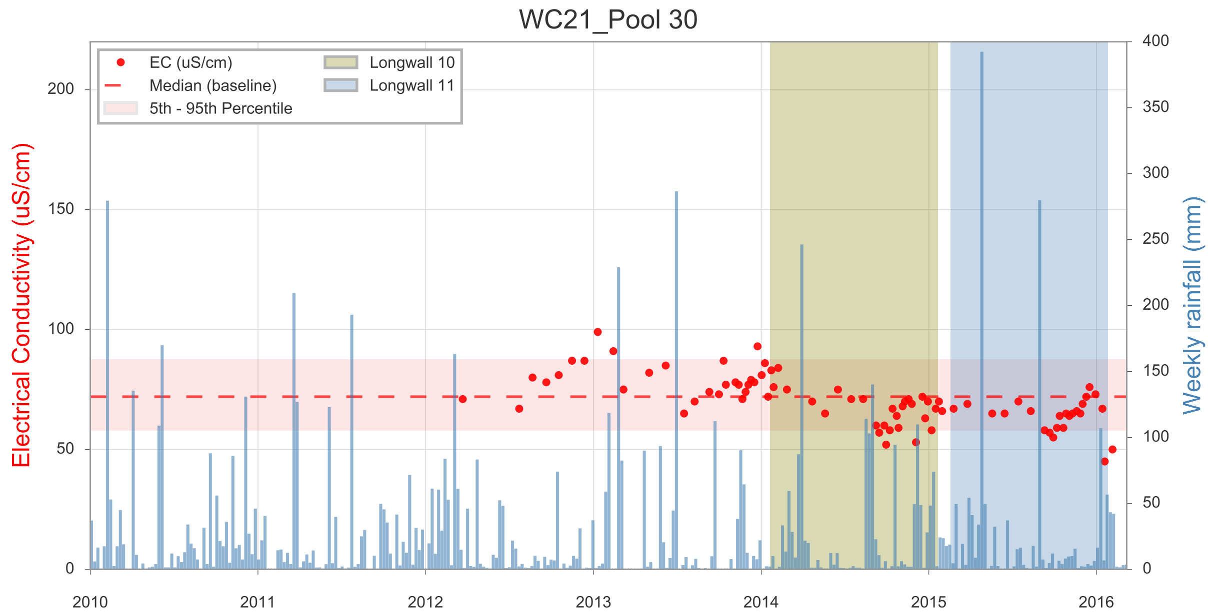
WC_S1
EC (uS/cm)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Electrical Conductivity (uS/cm)
Weekly rainfall (mm)

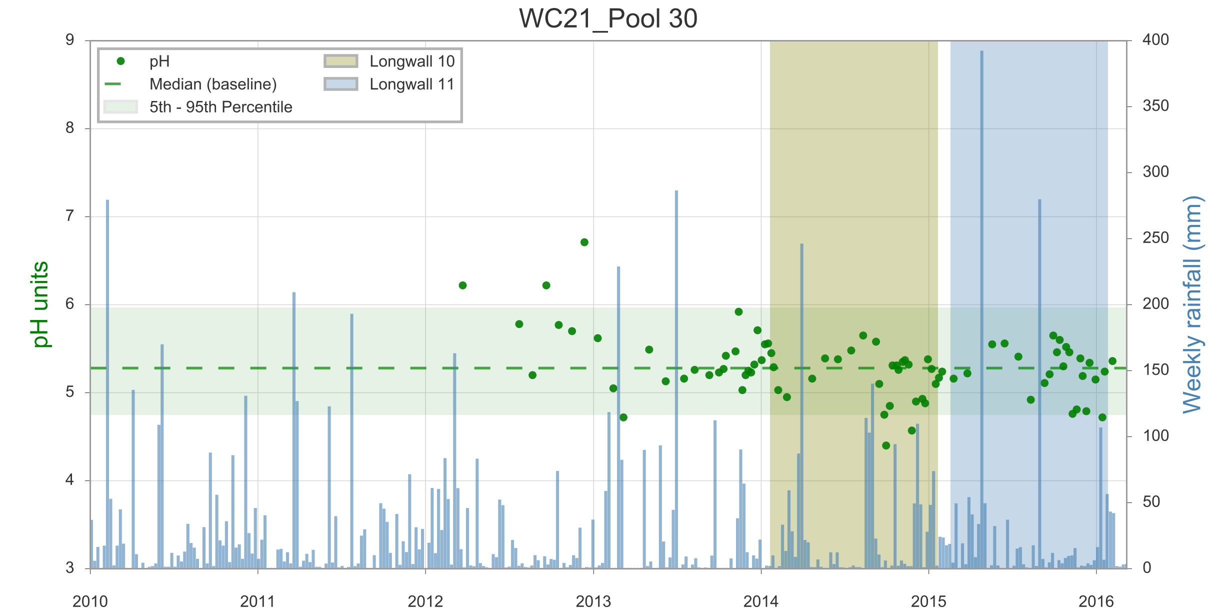


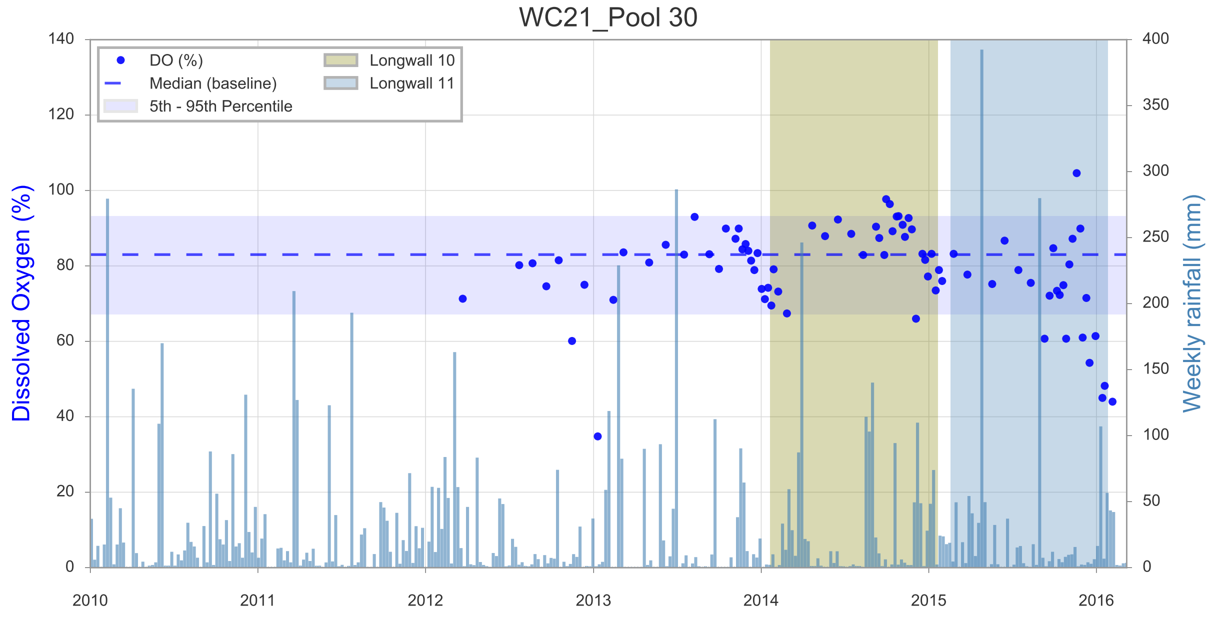
WC_S1
pH
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
pH units
Weekly rainfall (mm)

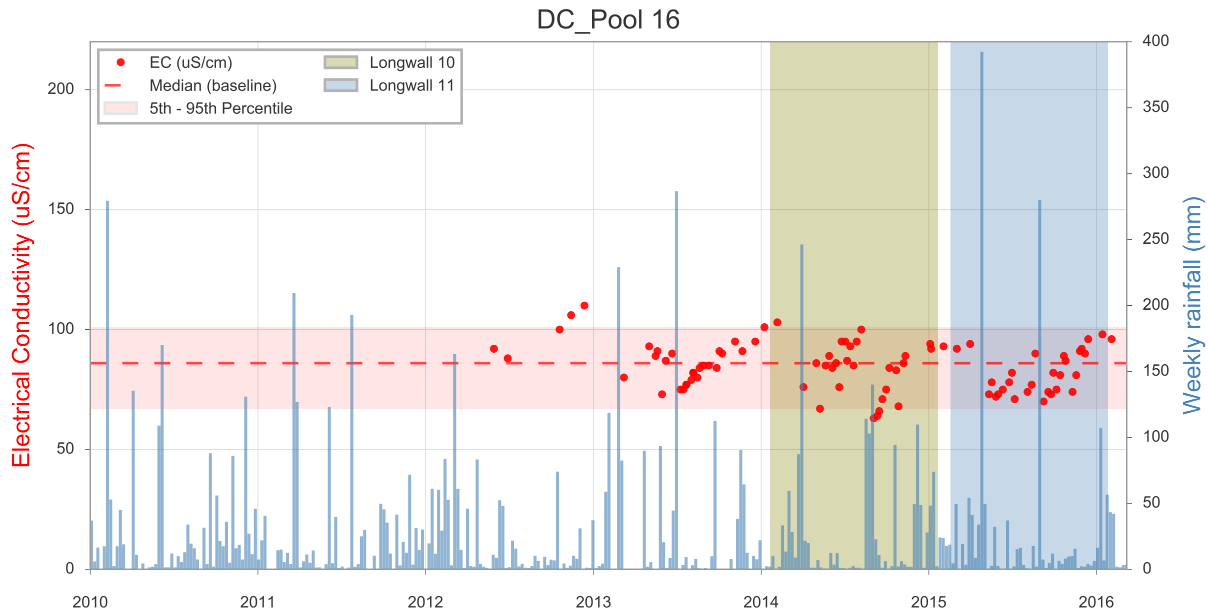


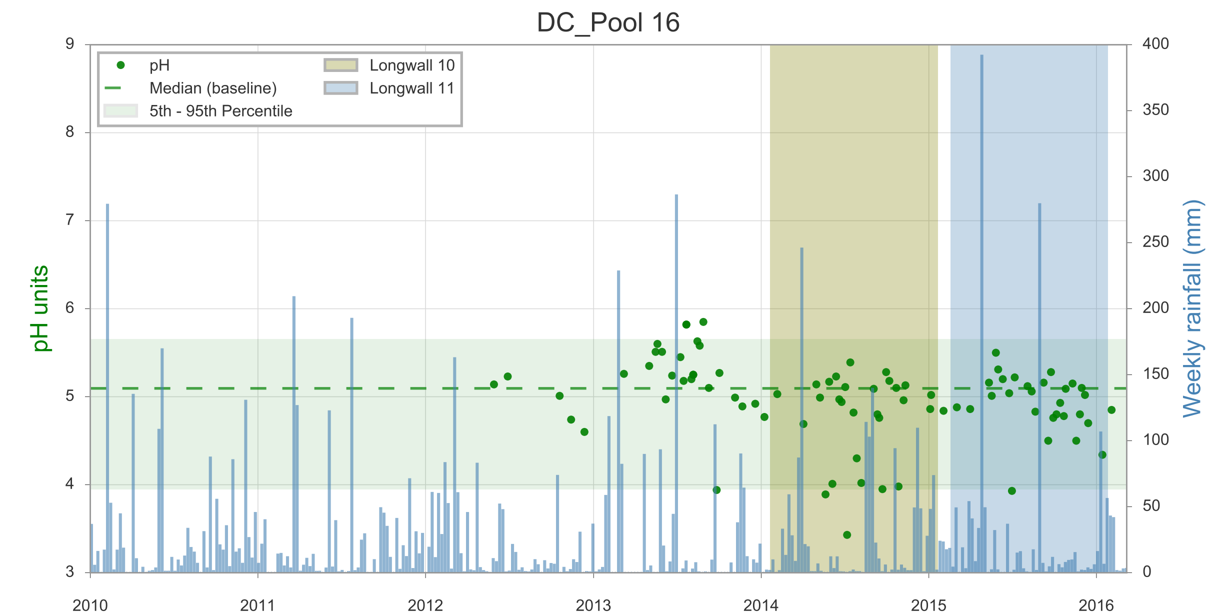
WC_S1
DO (%)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Dissolved Oxygen (%)
Weekly rainfall (mm)

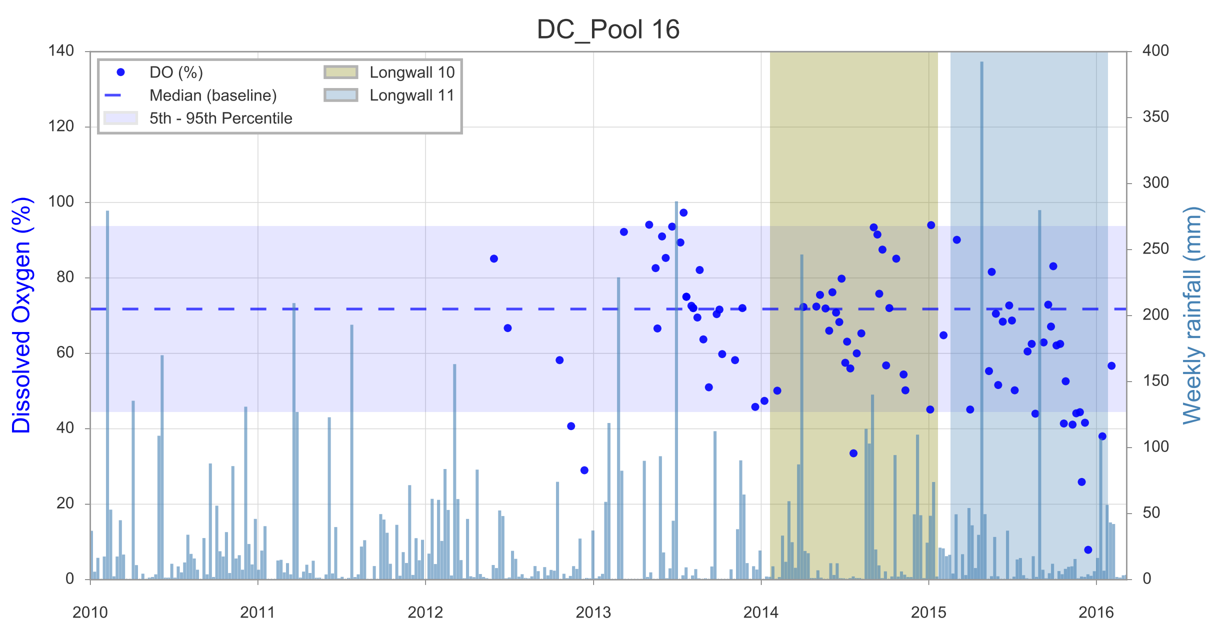

WC21_Pool 30
EC (uS/cm)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Electrical Conductivity (uS/cm)
Weekly rainfall (mm)
0
50
100
150
200
400
350
300
250
2010
2011
2012
2013
2014
2015
2016

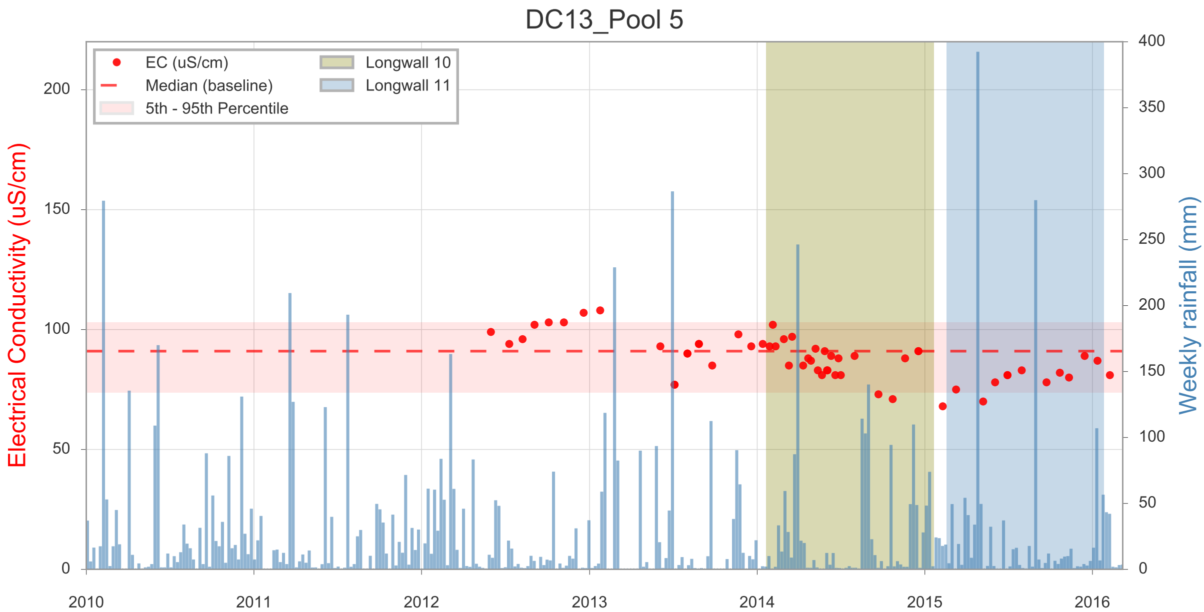

WC21_Pool 30
pH
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
pH units
Weekly rainfall (mm)
3
4
5
6
7
8
9
2010
2011
2012
2013
2014
2015
2016

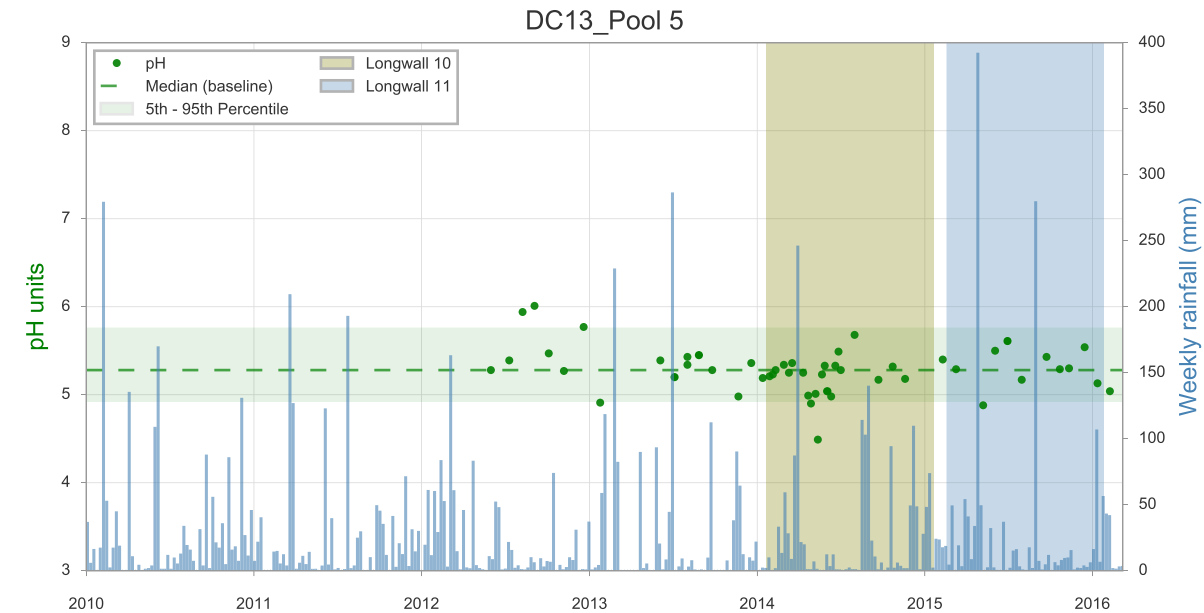

WC21_Pool 30
DO (%)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Dissolved Oxygen (%)
Weekly rainfall (mm)
0
20
40
60
80
100
120
140
2010
2011
2012
2013
2014
2015
2016

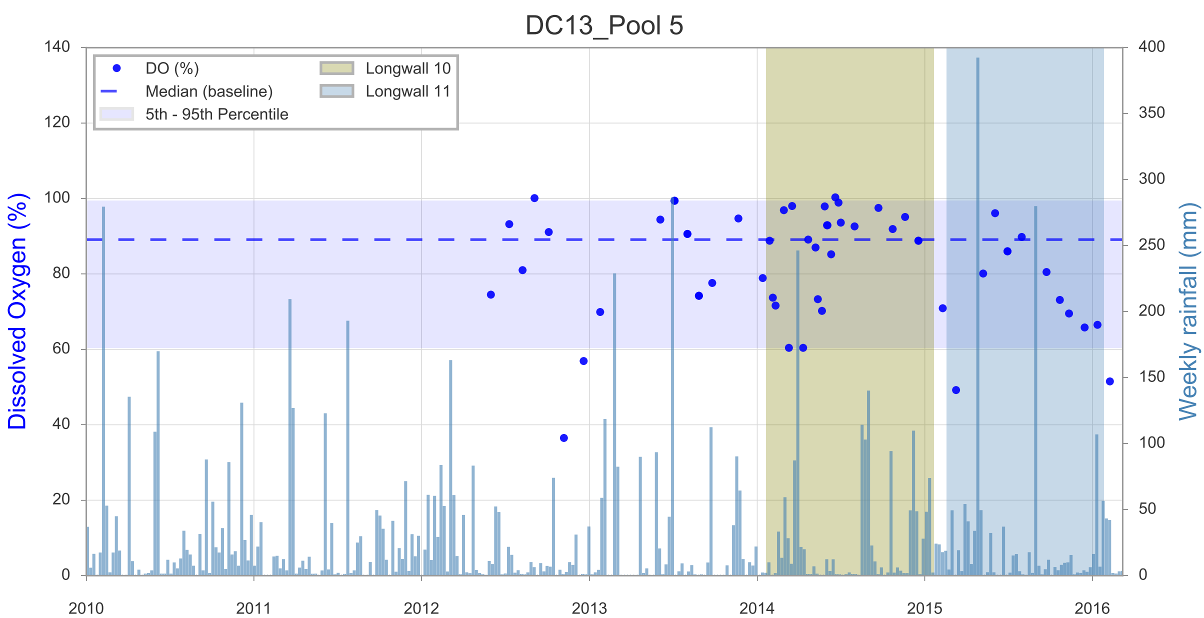

DC_Pool 16
EC (uS/cm)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Electrical Conductivity (uS/cm)
Weekly rainfall (mm)

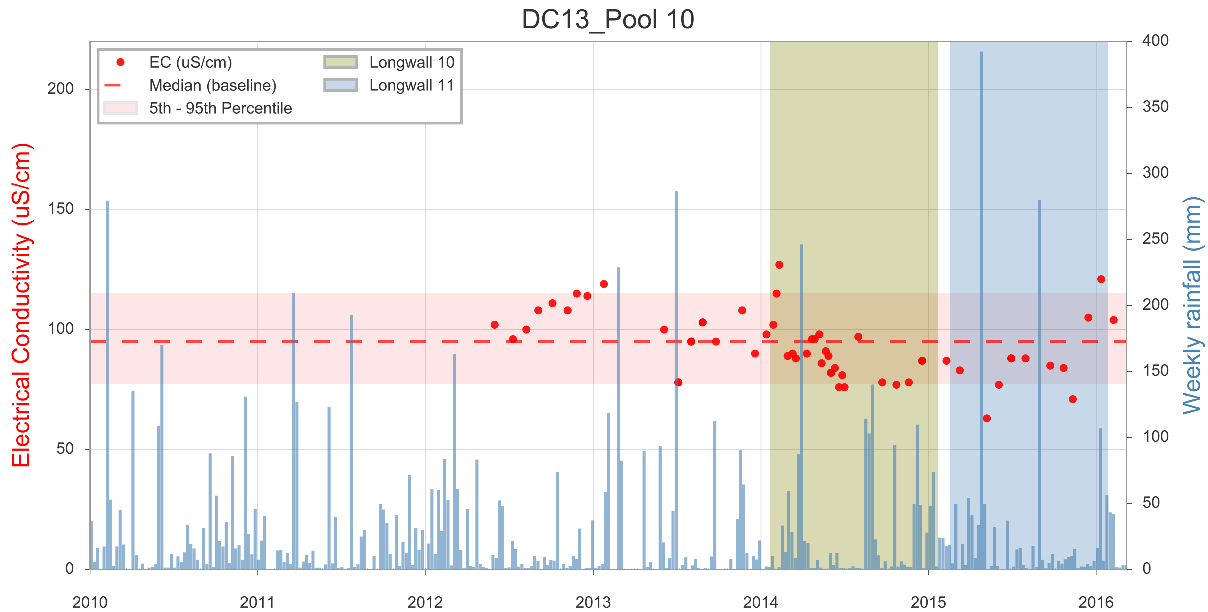

DC_Pool 16
pH
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
pH units
Weekly rainfall (mm)

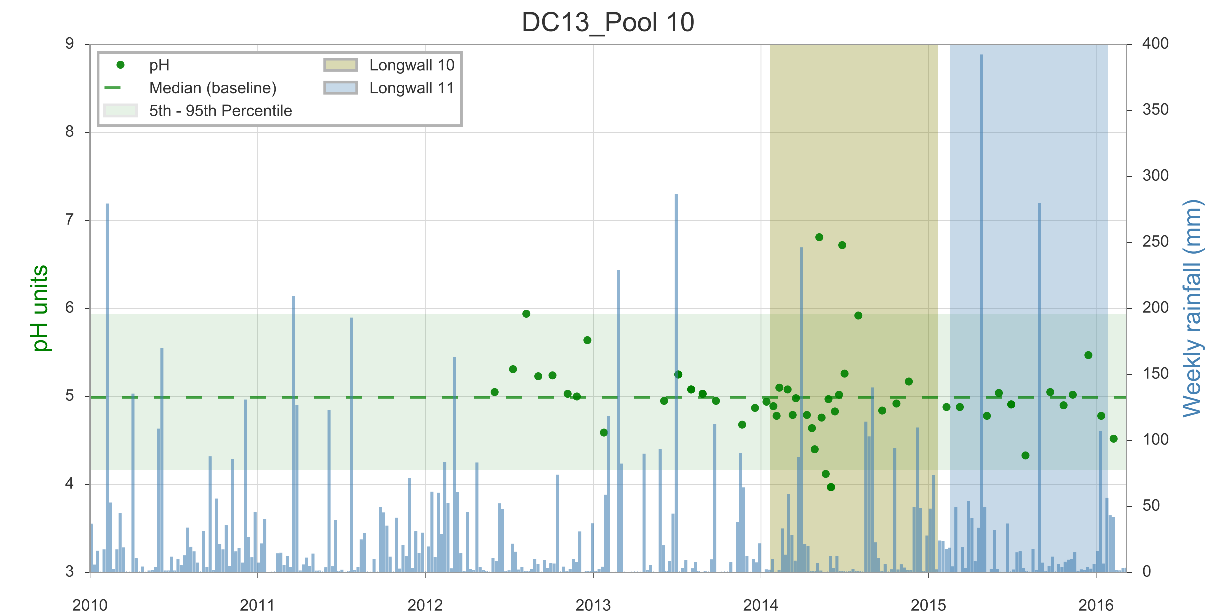

DC_Pool 16
DO (%)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Dissolved Oxygen (%)
Weekly rainfall (mm)

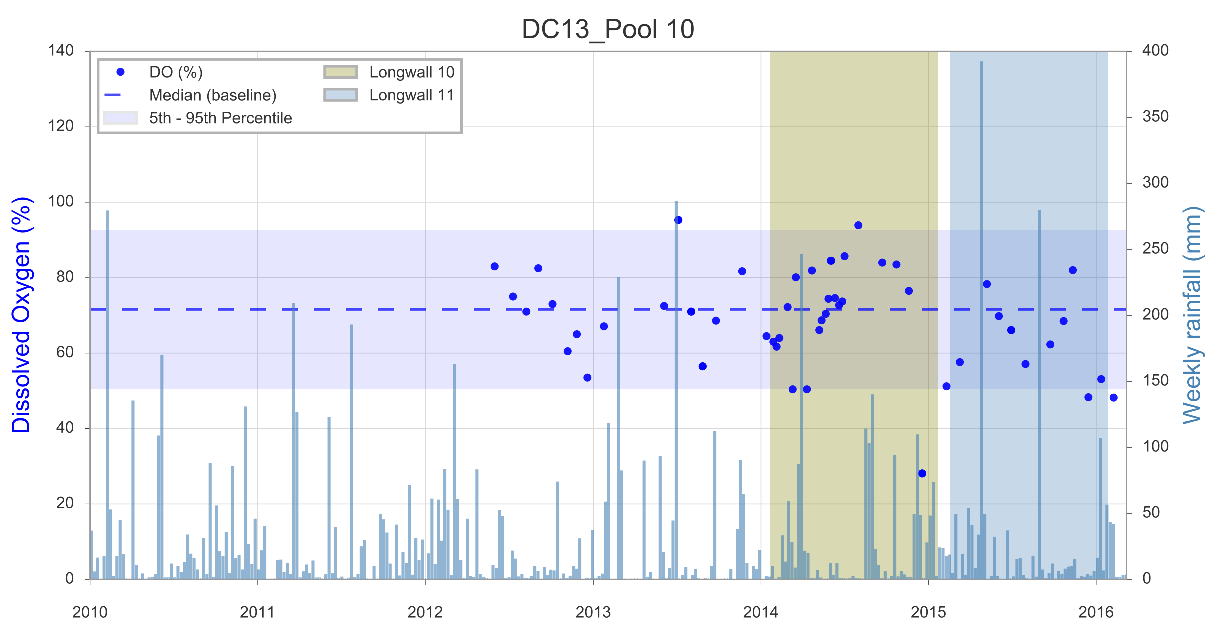

DC13_Pool 5
EC (uS/cm)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Electrical Conductivity (uS/cm)
Weekly rainfall (mm)
0
50
100
150
200
400
350
300
250
200
150
100
50
0
2010
2011
2012
2013
2014
2015
2016

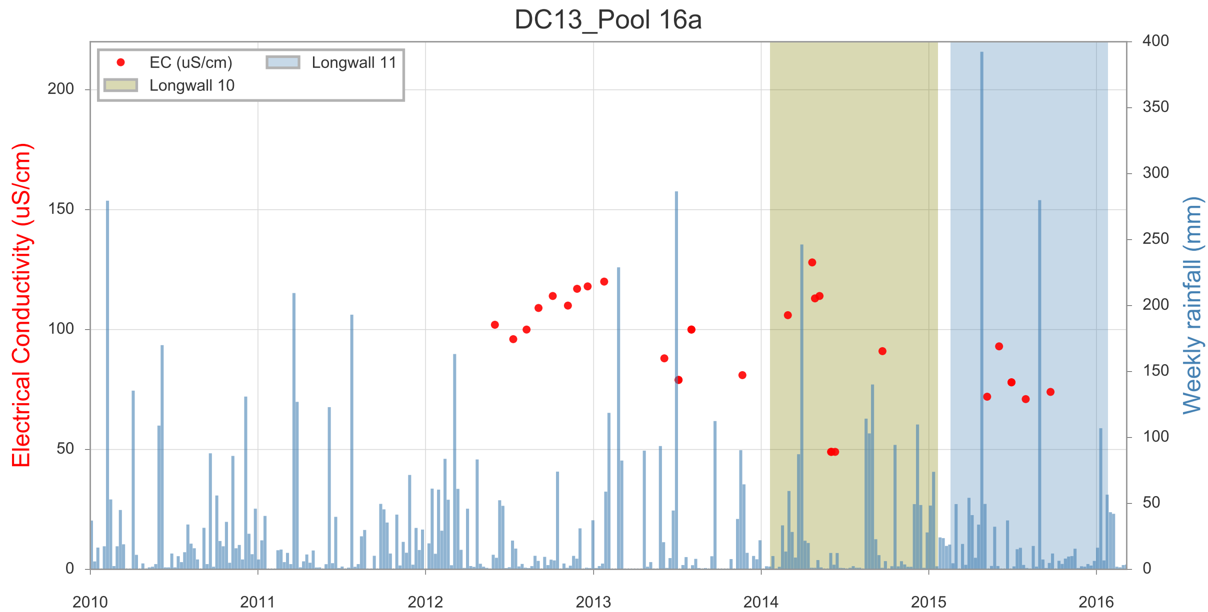

DC13_Pool 5
pH
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
pH units
Weekly rainfall (mm)
3
4
5
6
7
8
9
400
350
300
250
200
150
100
50
0
2010
2011
2012
2013
2014
2015
2016

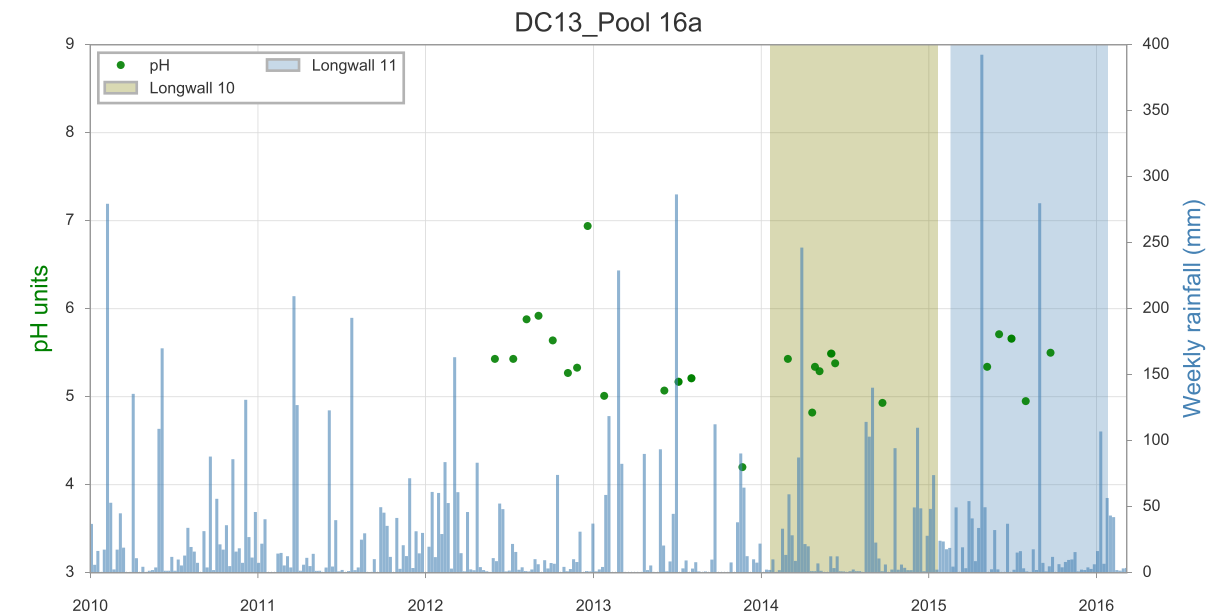

DC13_Pool 5
DO (%)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Dissolved Oxygen (%)
Weekly rainfall (mm)
0
20
40
60
80
100
120
140
400
350
300
250
200
150
100
50
0
2010
2011
2012
2013
2014
2015
2016

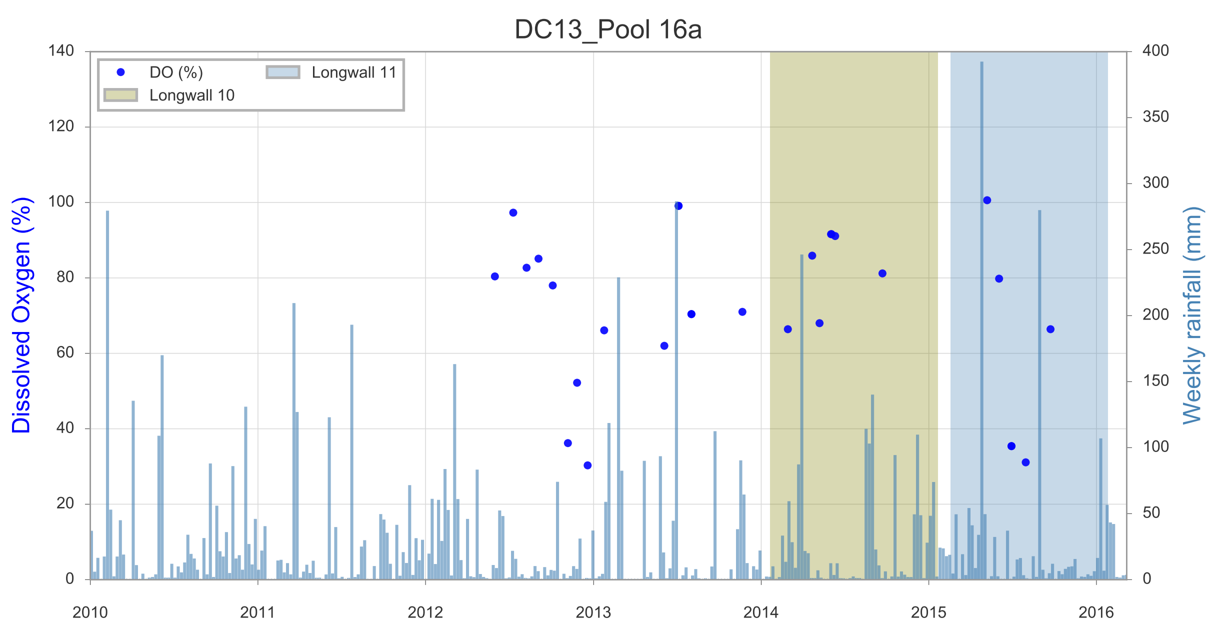

DC13_Pool 10
EC (uS/cm)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Electrical Conductivity (uS/cm)
Weekly rainfall (mm)
0
50
100
150
200
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016

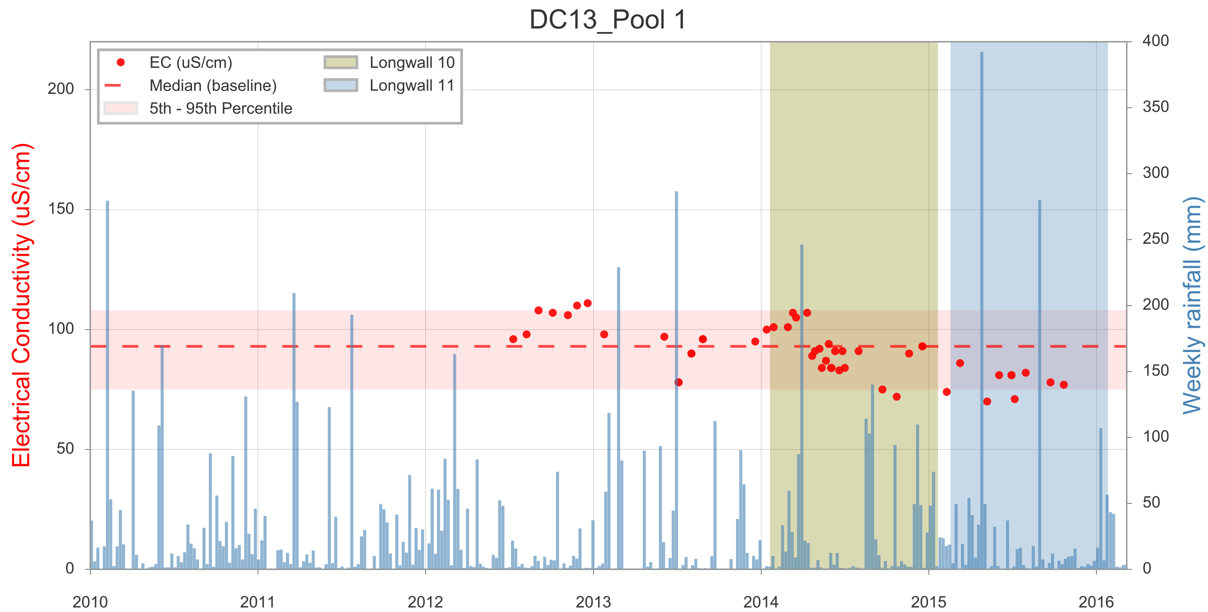

DC13_Pool 10
pH
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
pH units
Weekly rainfall (mm)
3
4
5
6
7
8
9
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016

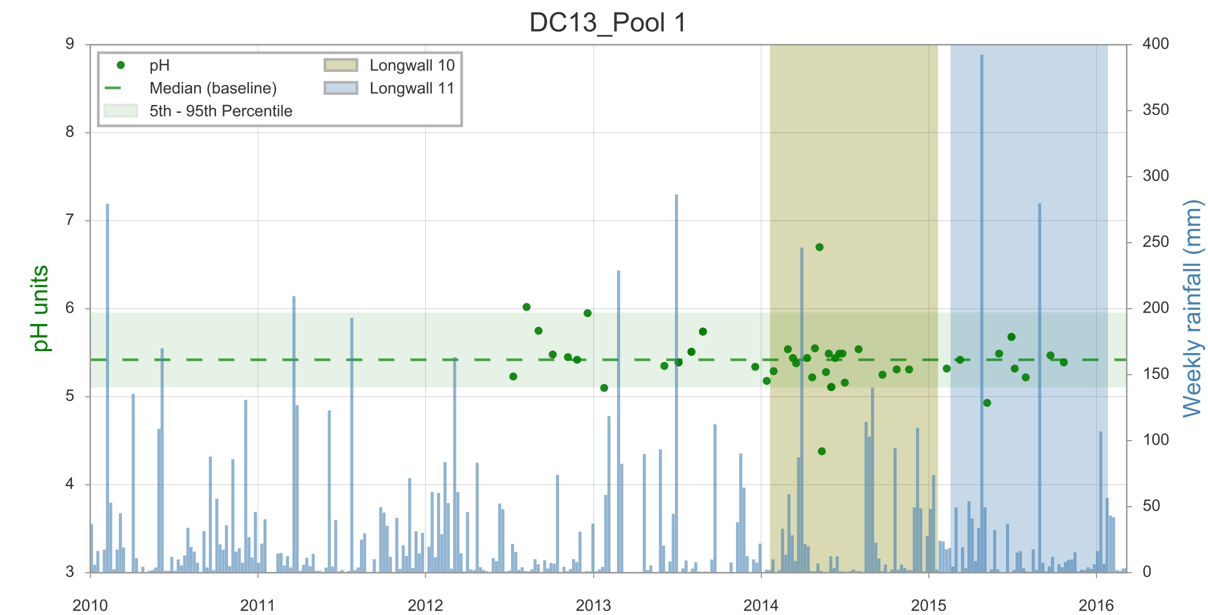

DC13_Pool 10
DO (%)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Dissolved Oxygen (%)
Weekly rainfall (mm)
0
20
40
60
80
100
120
140
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016

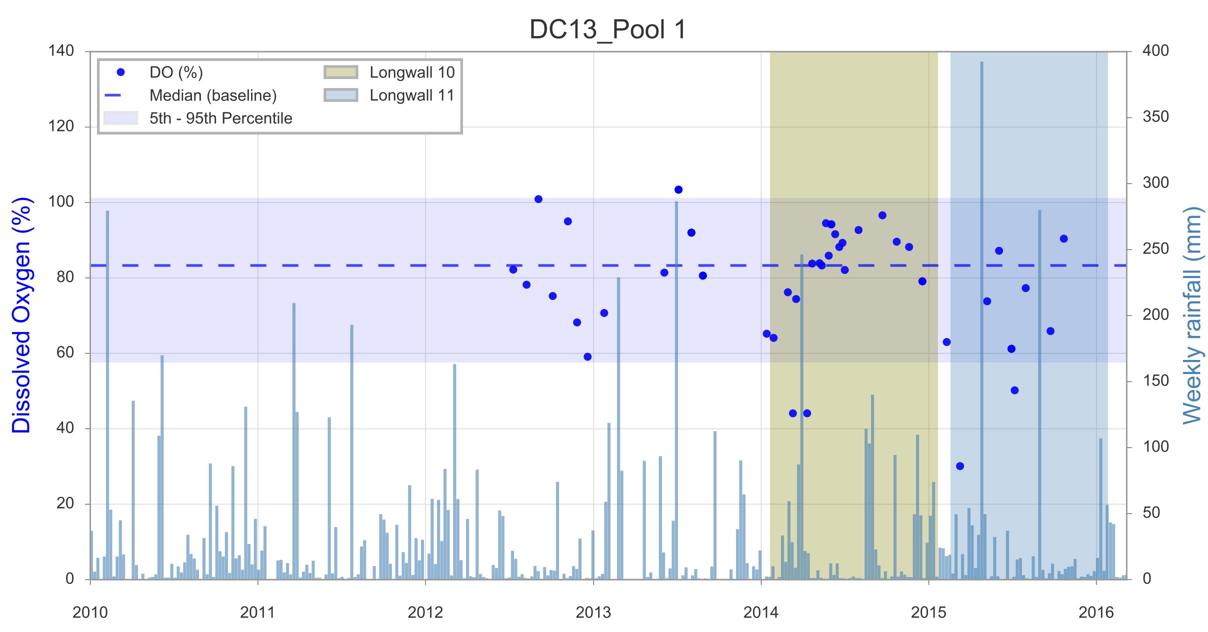

DC13_Pool 16a
EC (uS/cm)
Longwall 10
Longwall 11
Electrical Conductivity (uS/cm)
Weekly rainfall (mm)
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016

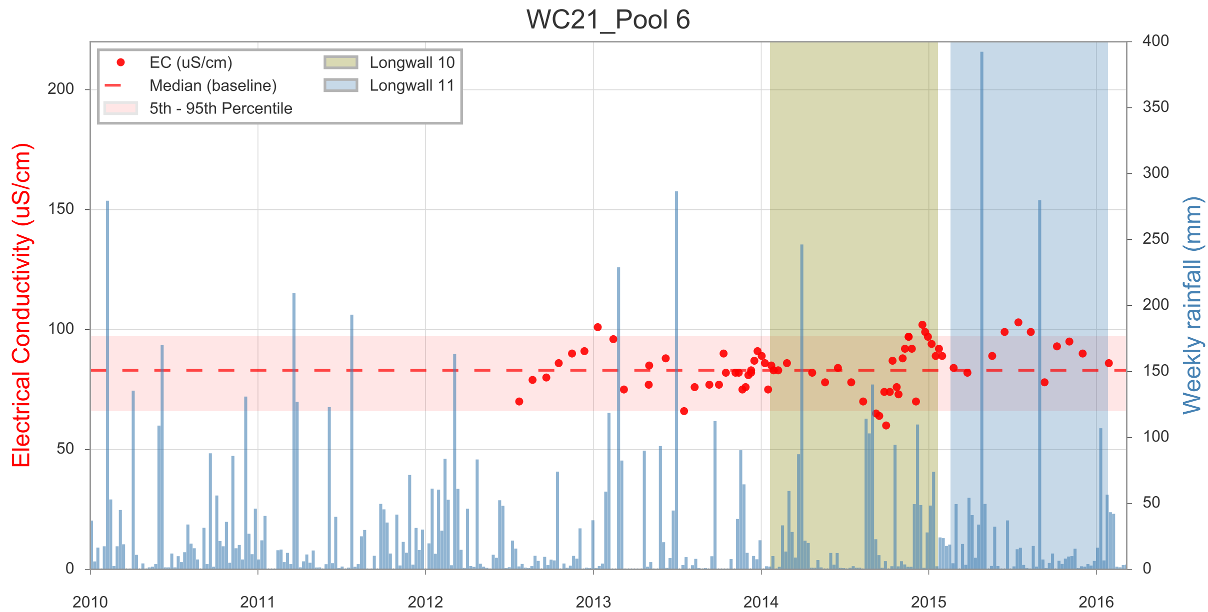

DC13_Pool 16a
pH
Longwall 10
Longwall 11
pH units
Weekly rainfall (mm)
3
4
5
6
7
8
9
2010
2011
2012
2013
2014
2015
2016

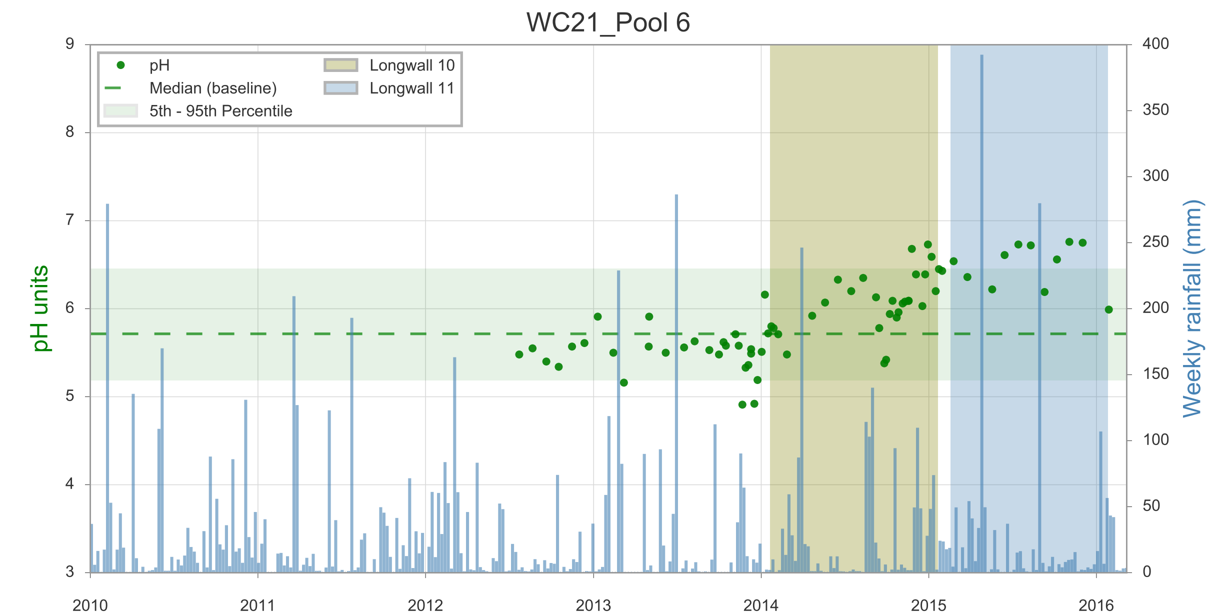

DC13_Pool 16a
DO (%)
Longwall 10
Longwall 11
Dissolved Oxygen (%)
Weekly rainfall (mm)
0
20
40
60
80
100
120
140
2010
2011
2012
2013
2014
2015
2016

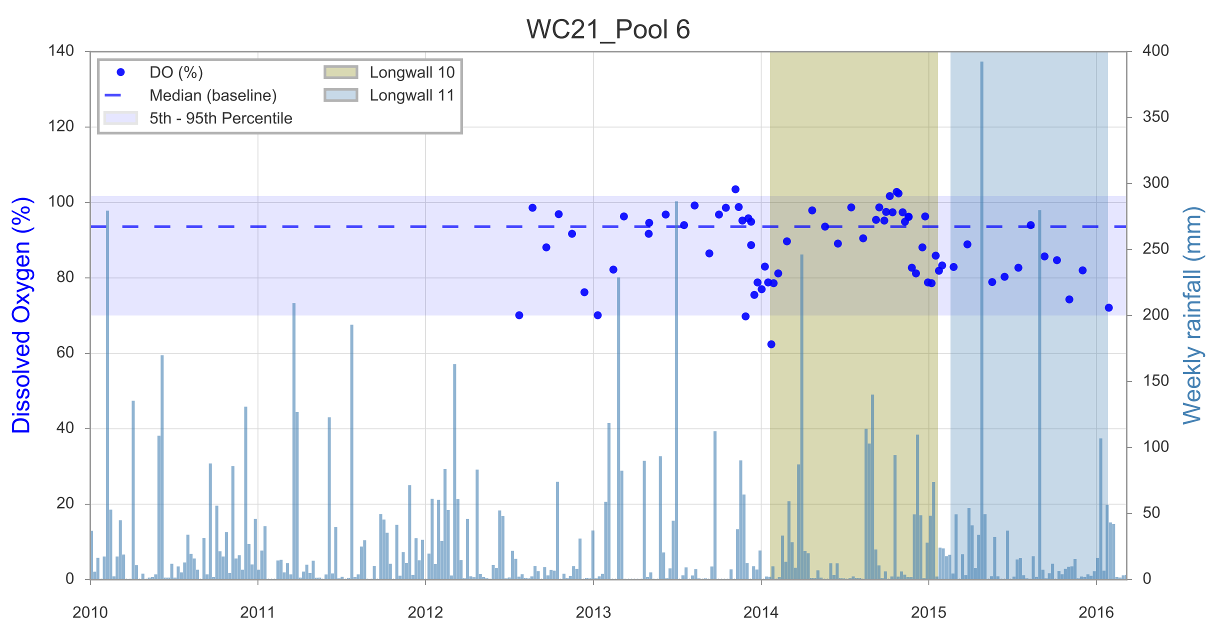

DC13_Pool 1
EC (uS/cm)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Electrical Conductivity (uS/cm)
Weekly rainfall (mm)
0
50
100
150
200
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016

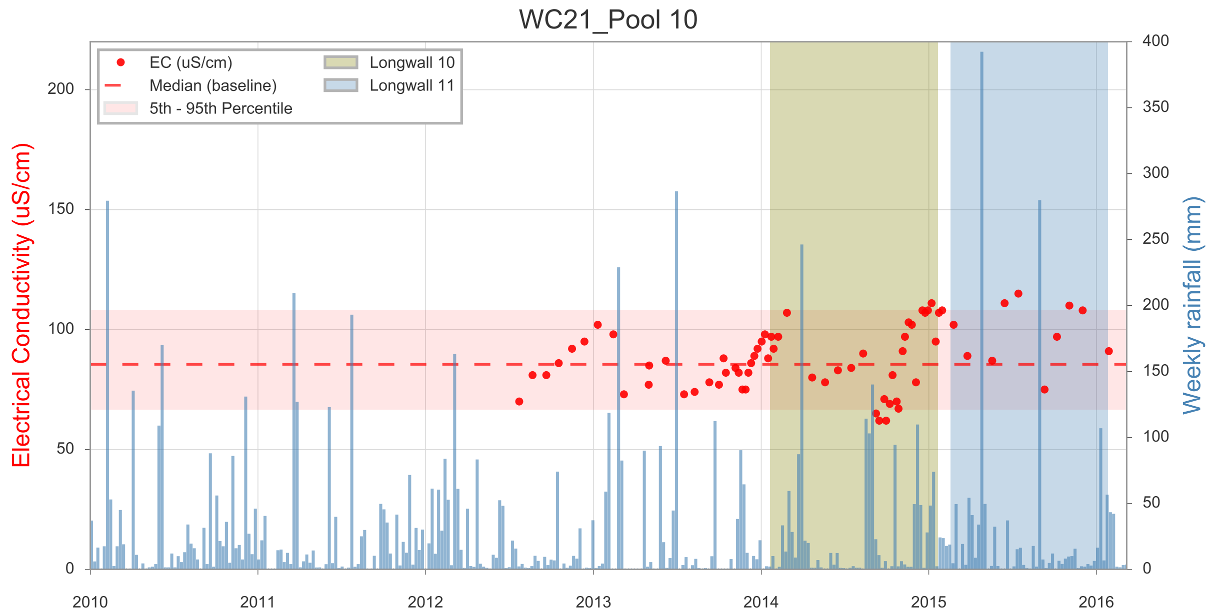

DC13_Pool 1
pH
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
pH units
Weekly rainfall (mm)
3
4
5
6
7
8
9
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016

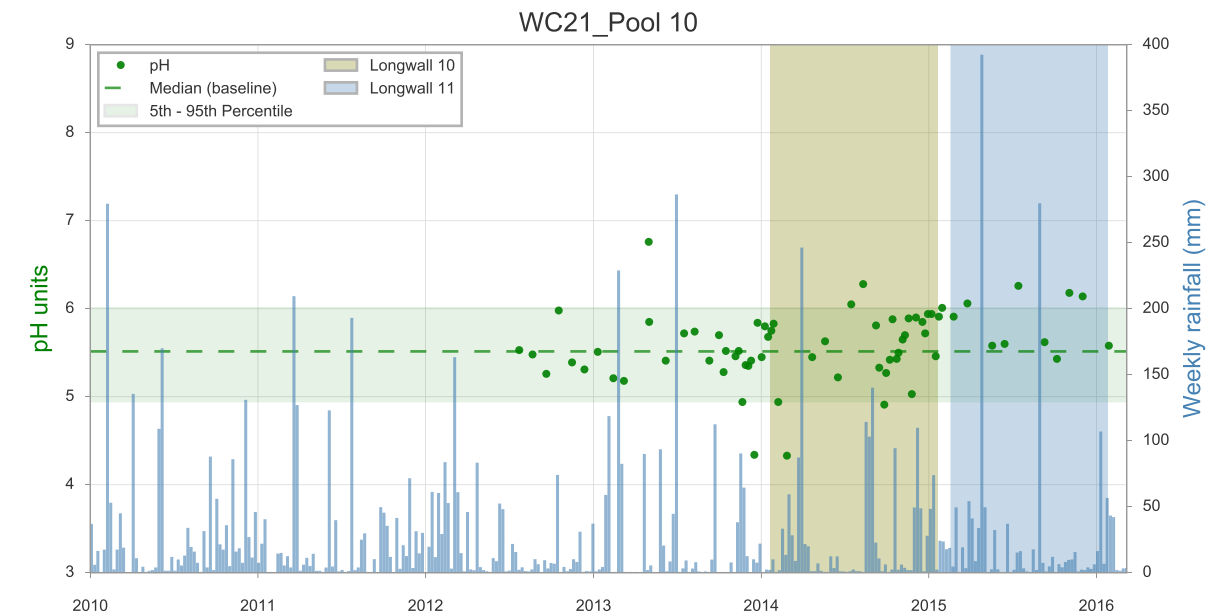

DC13_Pool 1
DO (%)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Dissolved Oxygen (%)
Weekly rainfall (mm)
0
20
40
60
80
100
120
140
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016

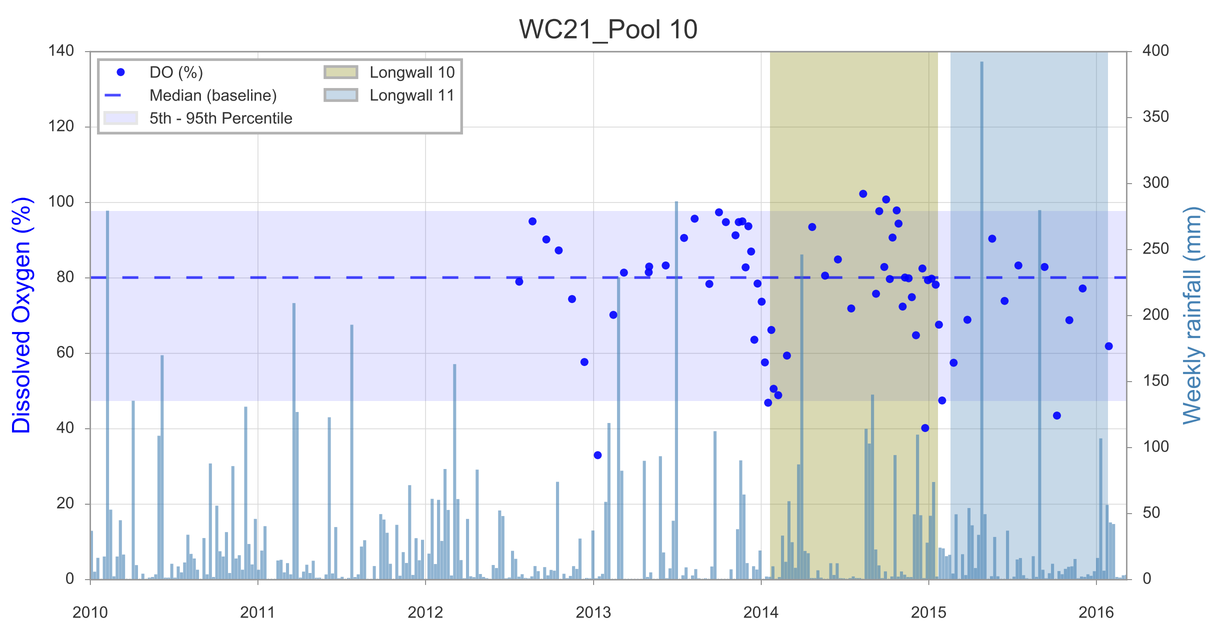

WC21_Pool 6
EC (uS/cm)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Electrical Conductivity (uS/cm)
Weekly rainfall (mm)
0
50
100
150
200
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016

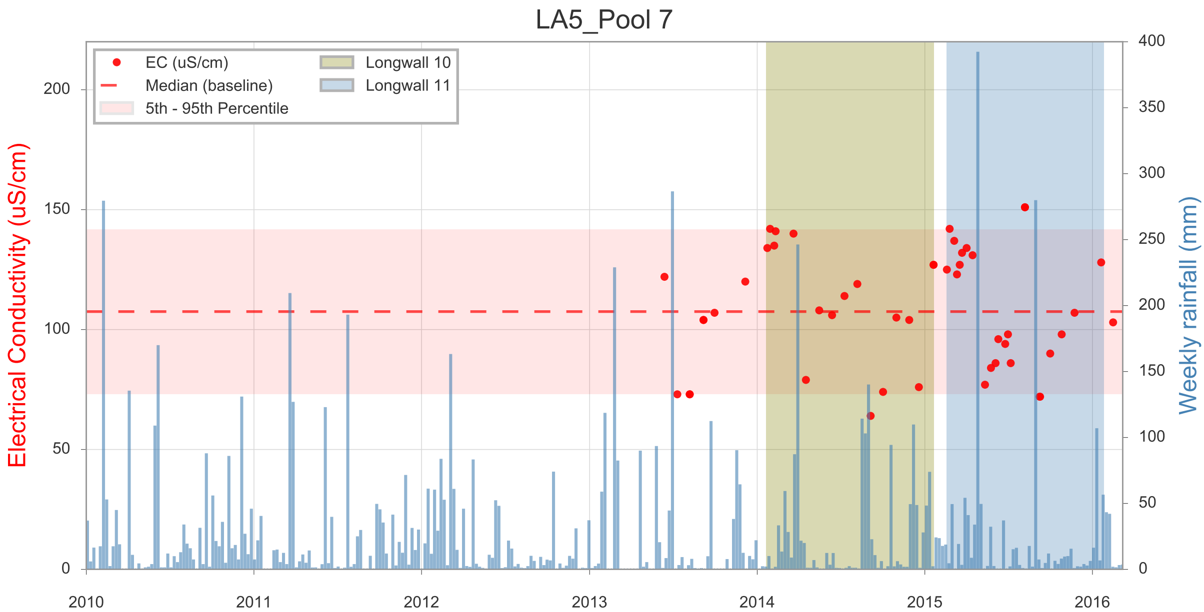

WC21_Pool 6
pH
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
pH units
Weekly rainfall (mm)
3
4
5
6
7
8
9
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016

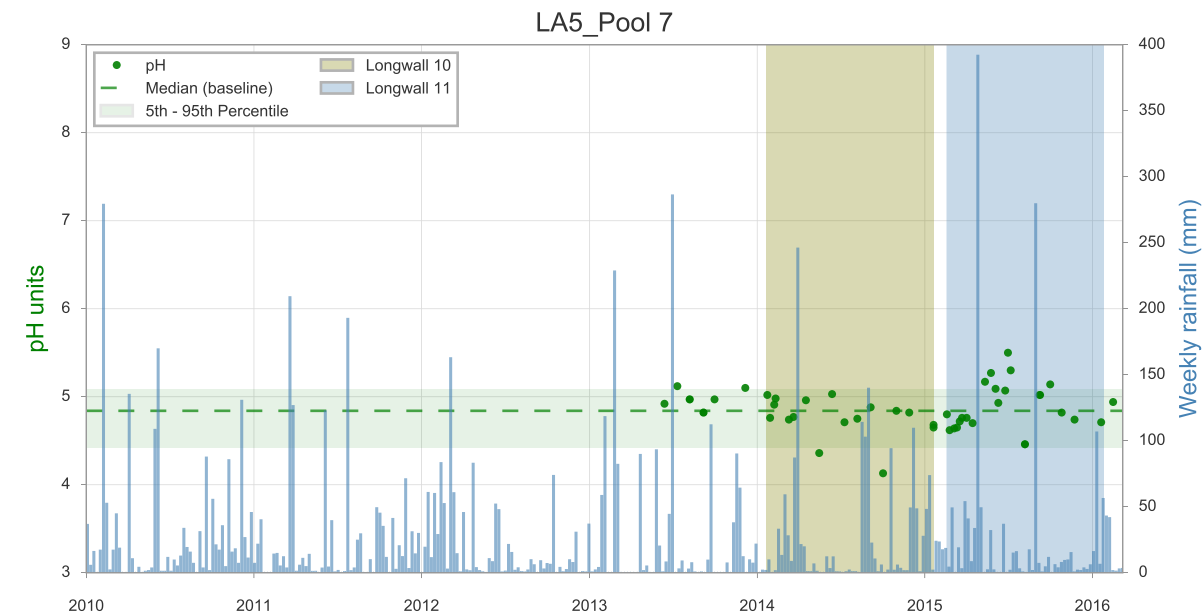

WC21_Pool 6
DO (%)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Dissolved Oxygen (%)
Weekly rainfall (mm)
0
20
40
60
80
100
120
140
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016

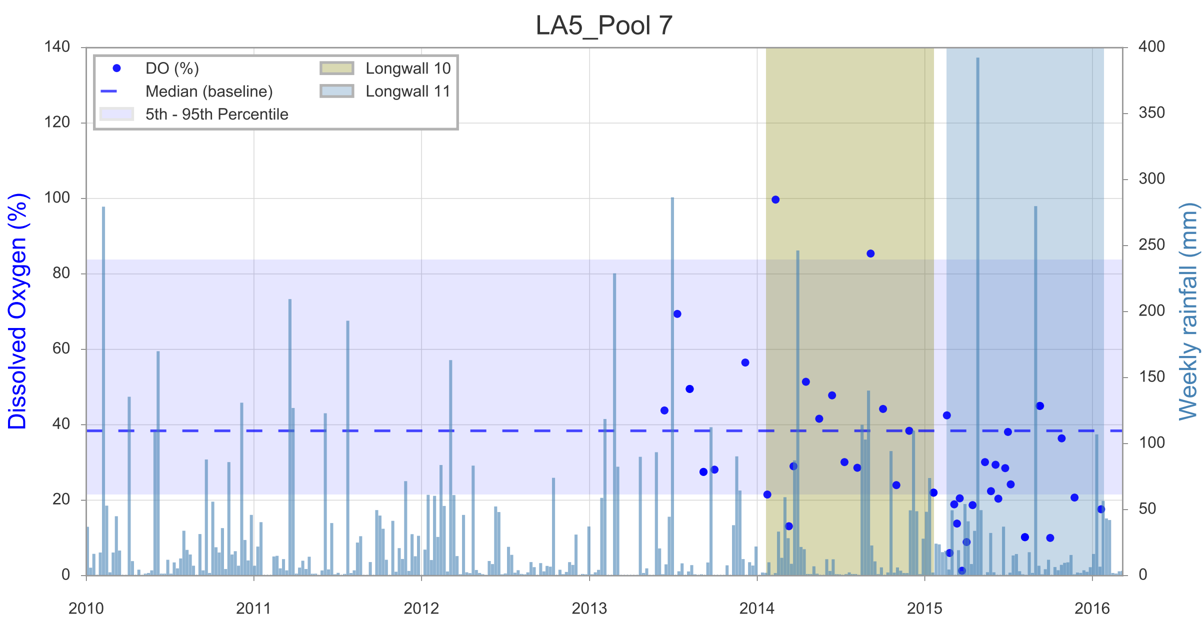

WC21_Pool 10
EC (uS/cm)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Electrical Conductivity (uS/cm)
Weekly rainfall (mm)
0
50
100
150
200
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016

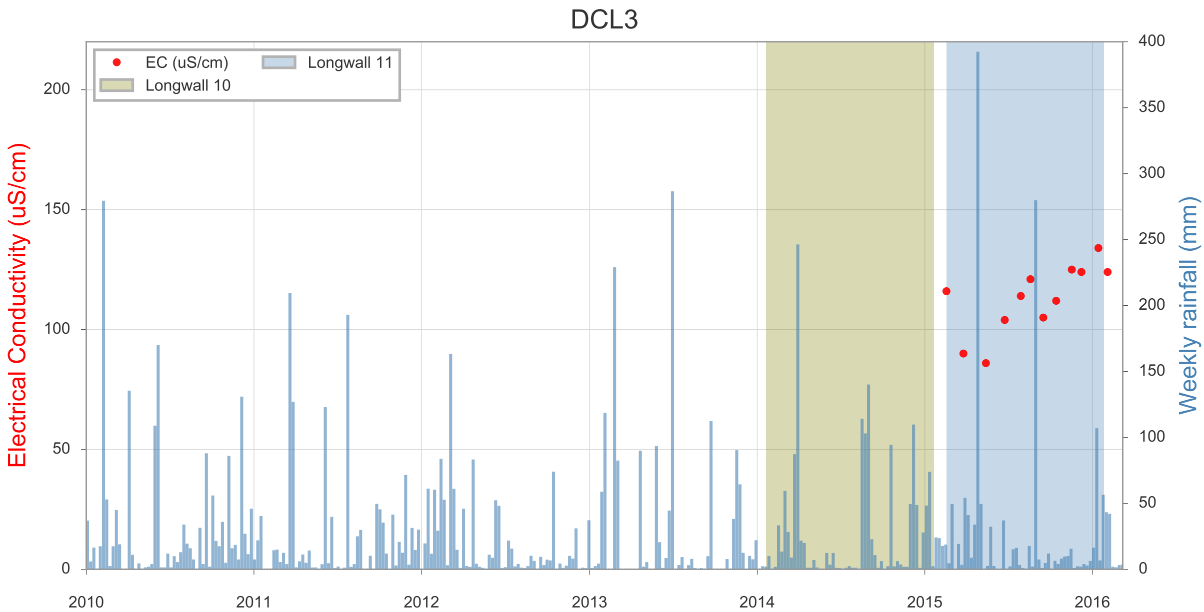

WC21_Pool 10
pH
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
pH units
Weekly rainfall (mm)
3
4
5
6
7
8
9
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016


WC21_Pool 10
DO (%)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Dissolved Oxygen (%)
Weekly rainfall (mm)
0
20
40
60
80
100
120
140
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016


LA5_Pool 7
EC (uS/cm)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Electrical Conductivity (uS/cm)
Weekly rainfall (mm)


LA5_Pool 7
pH
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
pH units
Weekly rainfall (mm)


LA5_Pool 7
DO (%)
Median (baseline)
5th - 95th Percentile
Longwall 10
Longwall 11
Dissolved Oxygen (%)
Weekly rainfall (mm)


DCL3
EC (uS/cm)
Longwall 10
Longwall 11
Electrical Conductivity (uS/cm)
Weekly rainfall (mm)
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50
100
150
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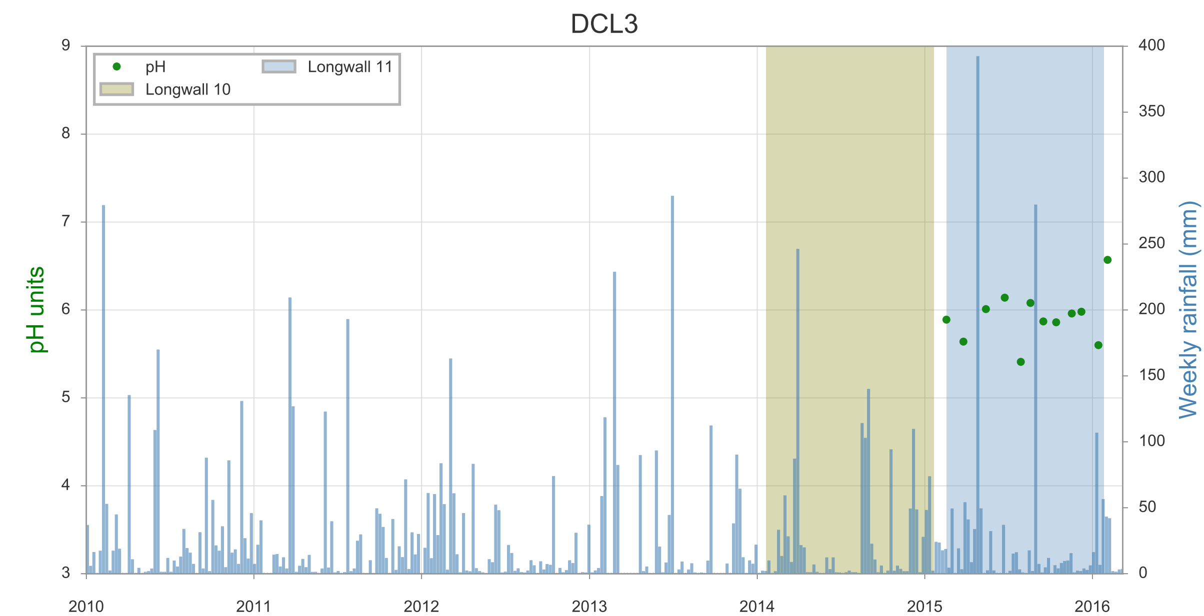
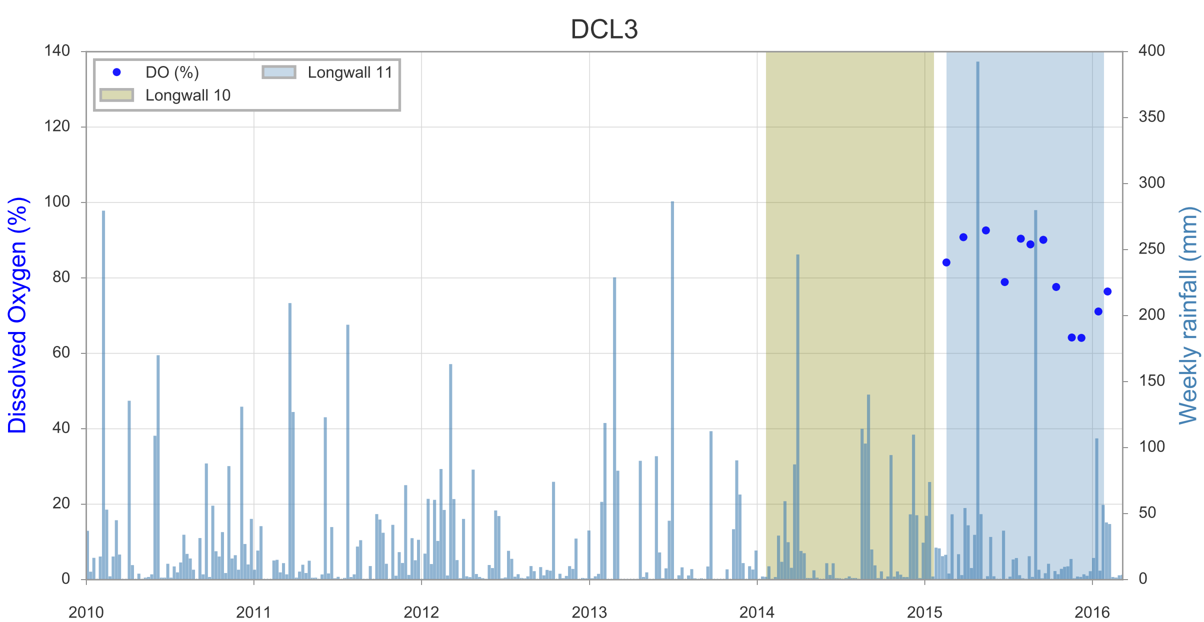
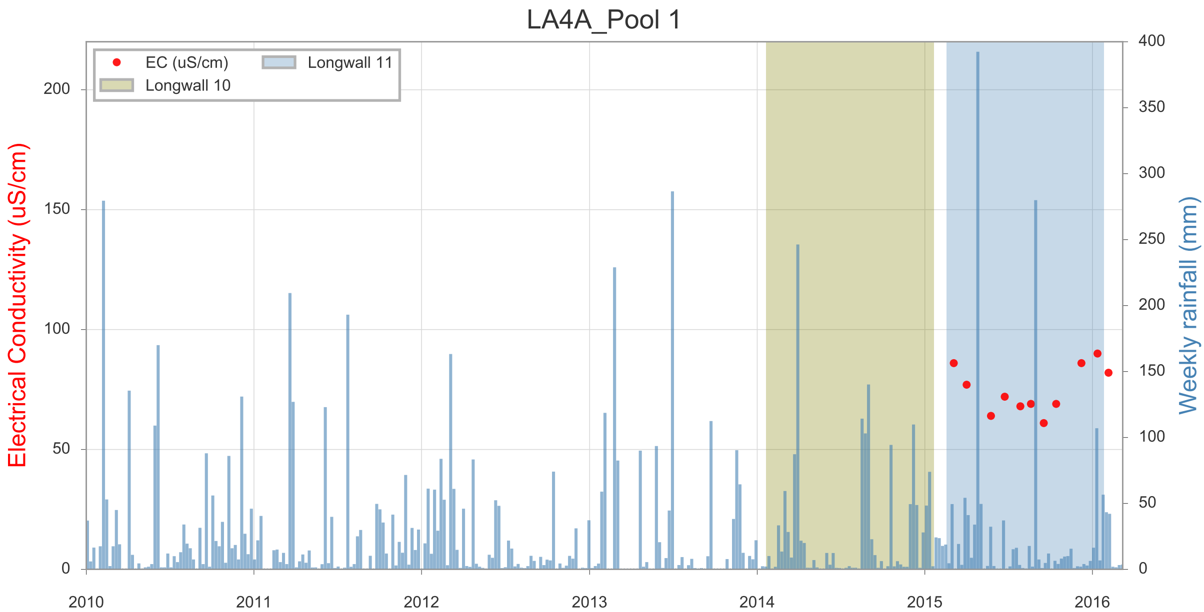
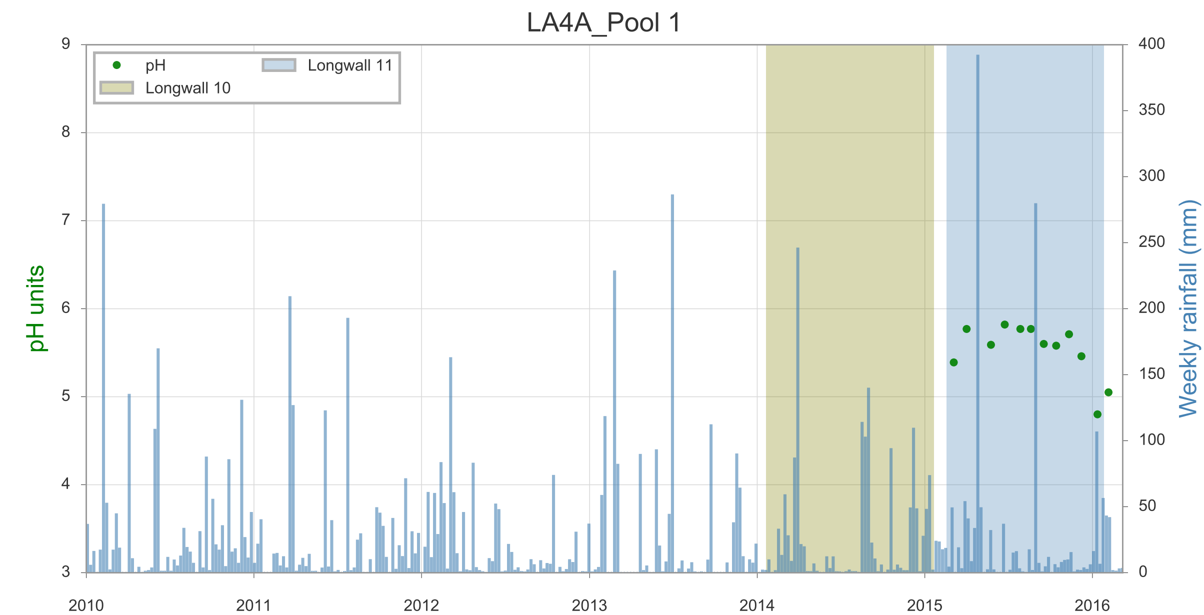
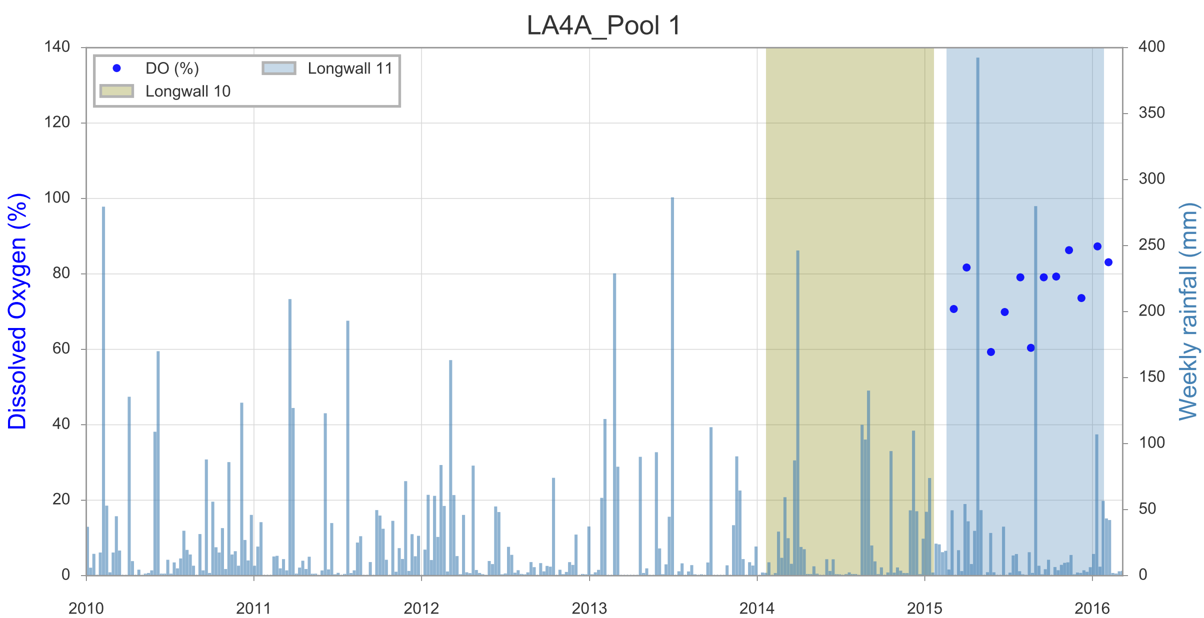
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016

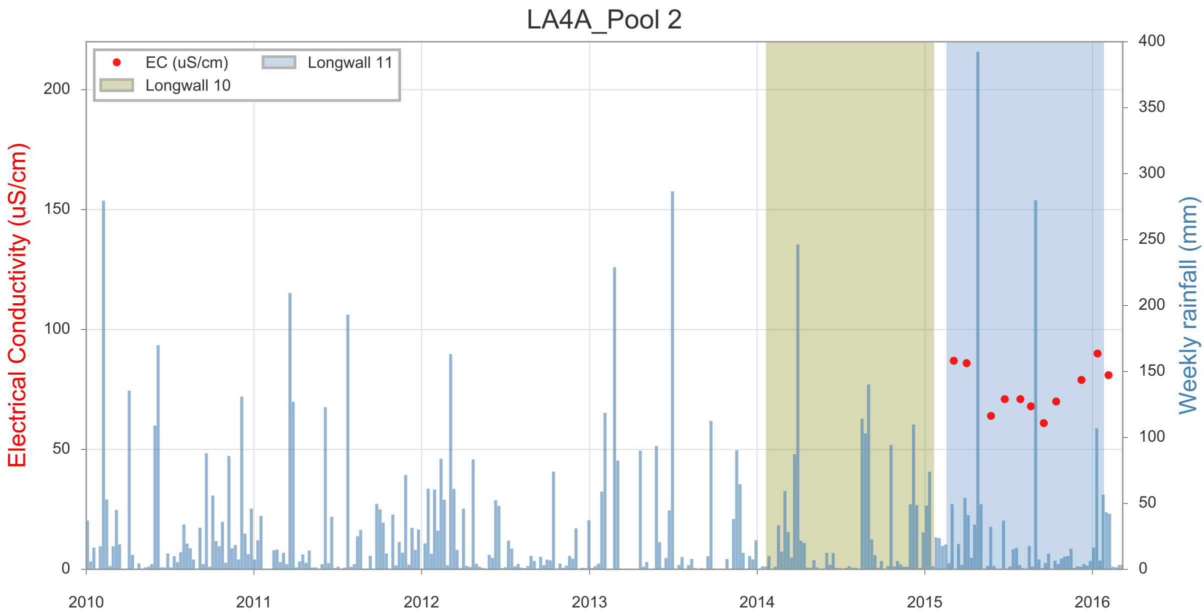

DCL3
pH
Longwall 10
Longwall 11
pH units
Weekly rainfall (mm)
3
4
5
6
7
8
9
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016

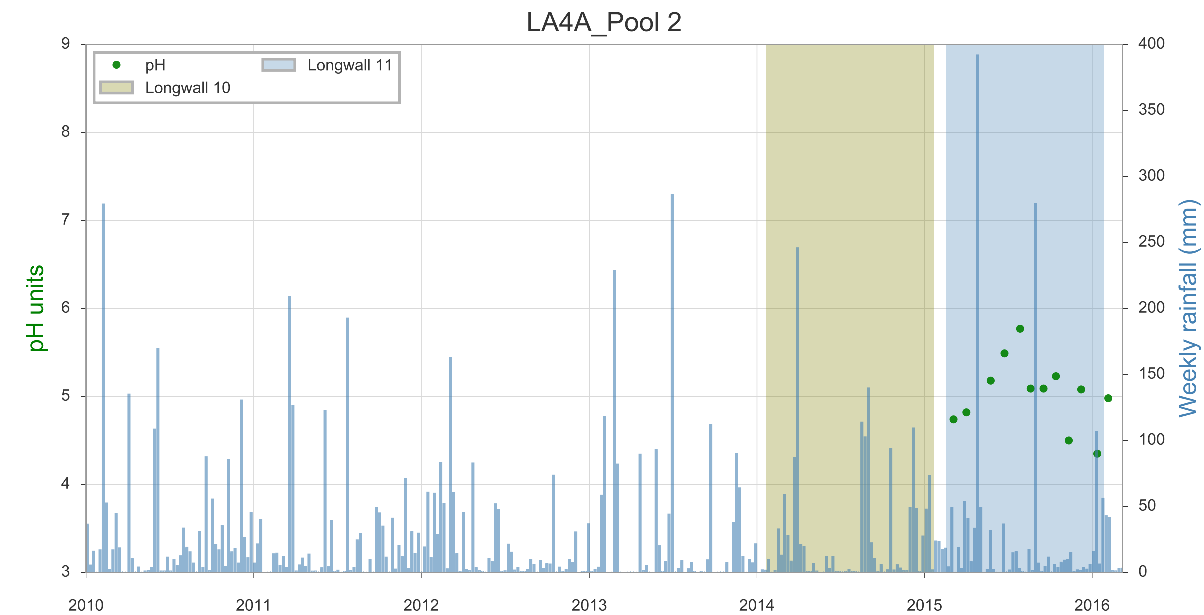

DCL3
DO (%)
Longwall 10
Longwall 11
Dissolved Oxygen (%)
Weekly rainfall (mm)
0
20
40
60
80
100
120
140
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016

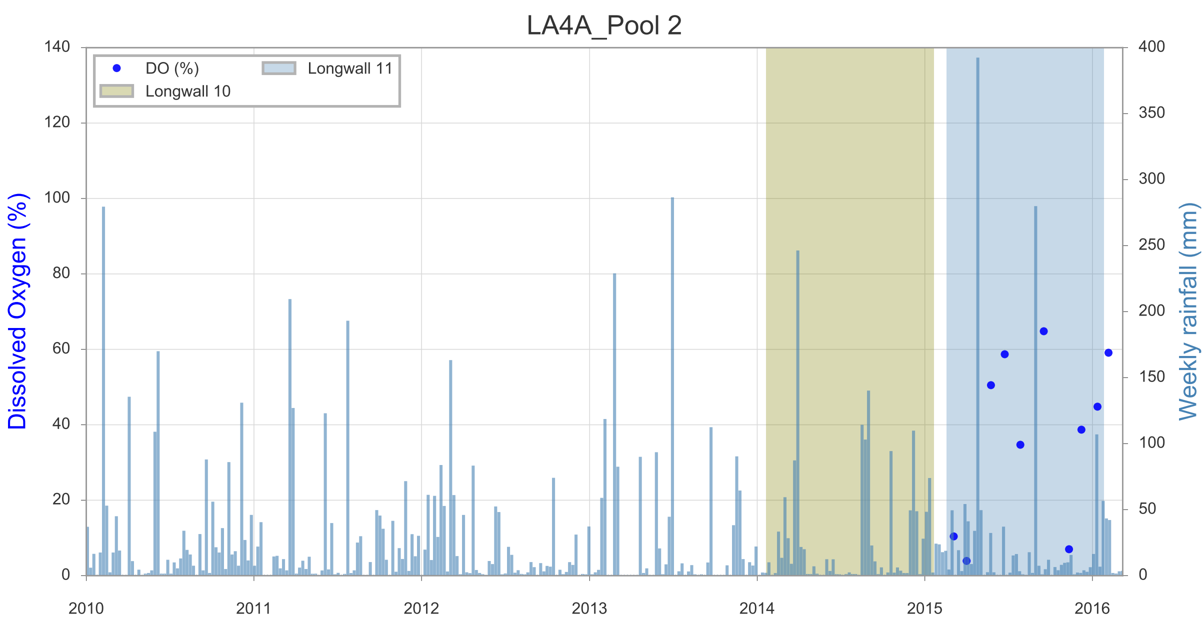

LA4A_Pool 1
EC (uS/cm)
Longwall 10
Longwall 11
Electrical Conductivity (uS/cm)
Weekly rainfall (mm)
0
50
100
150
200
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016


LA4A_Pool 1
pH
Longwall 10
Longwall 11
pH units
Weekly rainfall (mm)
3
4
5
6
7
8
9
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016


LA4A_Pool 1
DO (%)
Longwall 10
Longwall 11
Dissolved Oxygen (%)
Weekly rainfall (mm)
0
20
40
60
80
100
120
140
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016


LA4A_Pool 2
EC (uS/cm)
Longwall 10
Longwall 11
Electrical Conductivity (uS/cm)
Weekly rainfall (mm)
0
50
100
150
200
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016


LA4A_Pool 2
pH
Longwall 10
Longwall 11
pH units
Weekly rainfall (mm)
3
4
5
6
7
8
9
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016


LA4A_Pool 2
DO (%)
Longwall 10
Longwall 11
Dissolved Oxygen (%)
Weekly rainfall (mm)
0
20
40
60
80
100
120
140
0
50
100
150
200
250
300
350
400
2010
2011
2012
2013
2014
2015
2016

APPENDIX B

Parameters used for AWBM by modelled catchment

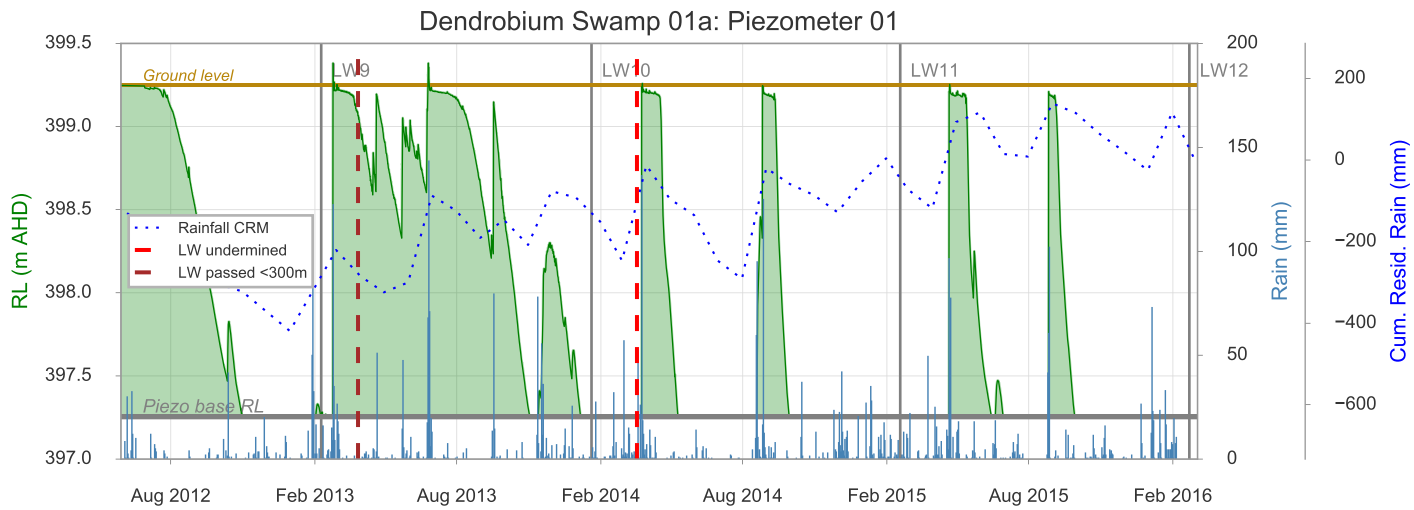
Table 7 AWBM parameters for Dendrobium catchment models

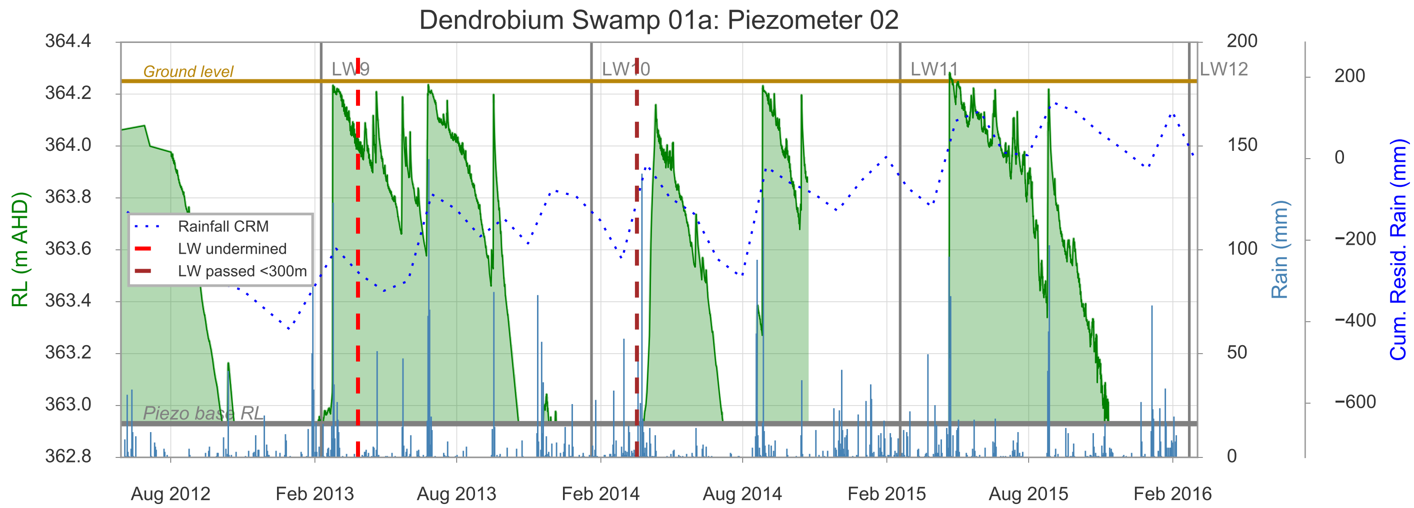
SITE	A1	A2	A3	Kbase	Ksurf	BFI	C1	C2	C3
	area - fraction	area - fraction	area - fraction	fraction	fraction	fraction	mm	mm	mm
Donalds Castle Creek catchments									
DC2	0.15	0.2	0.65	0.97	0.26	0.32	0.008	0.12	0.27
DC13	0.08	0.433	0.487	0.982	0.22	0.34	0.015	0.14	0.37
DCU	0.15	0.2	0.65	0.97	0.26	0.32	0.008	0.12	0.27
Wongawilli Creek catchments									
WC15	0.15	0.2	0.65	0.97	0.26	0.32	0.008	0.12	0.27
WC21	0.134	0.433	0.433	0.974	0.35	0.42	0.001	0.12	0.25
WWL	0.134	0.433	0.433	0.97	0.26	0.32	0.01	0.1	0.25
Lake Avon tributaries									
LA4	0.134	0.433	0.433	0.97	0.26	0.32	0.01	0.1	0.25

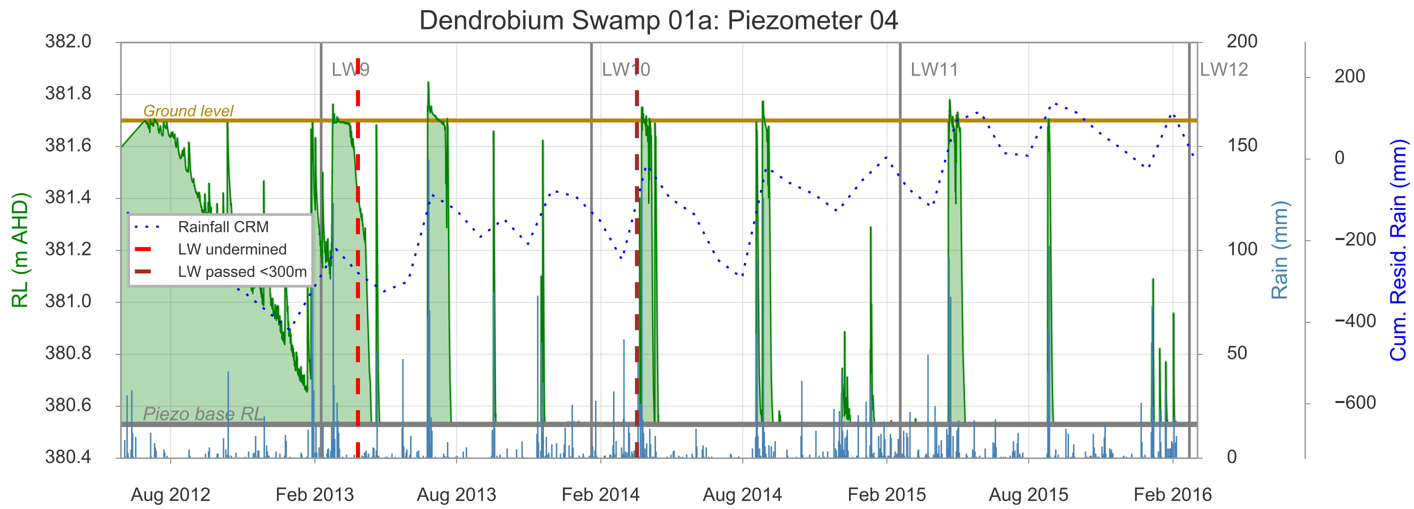
APPENDIX C

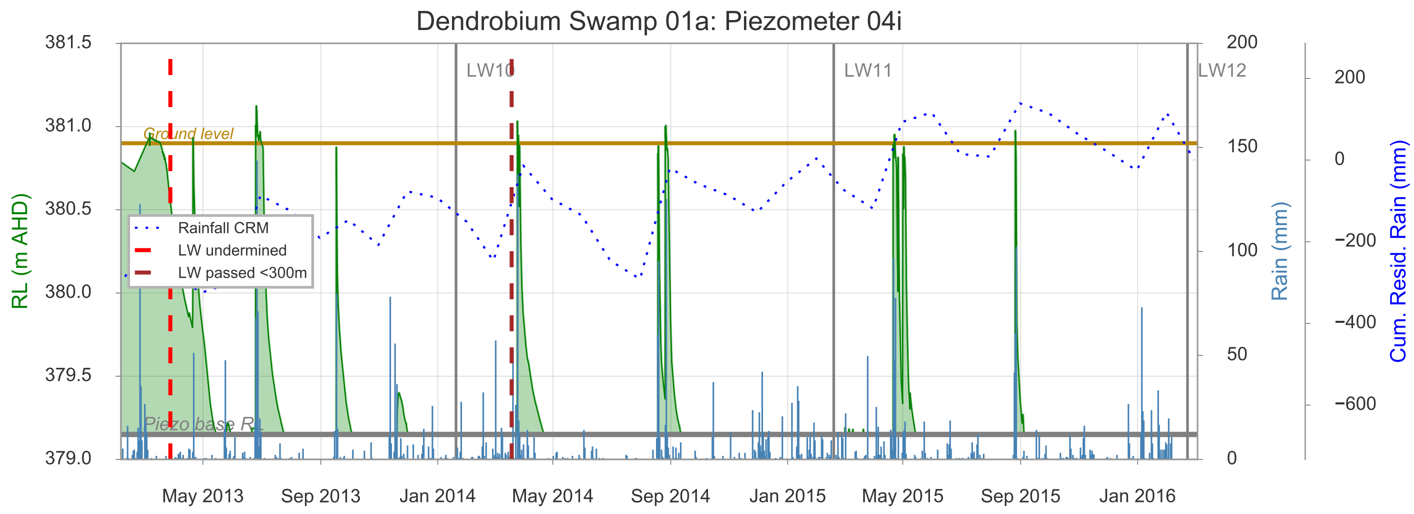
Assessment of Shallow Piezometer (Swamp) Behaviour

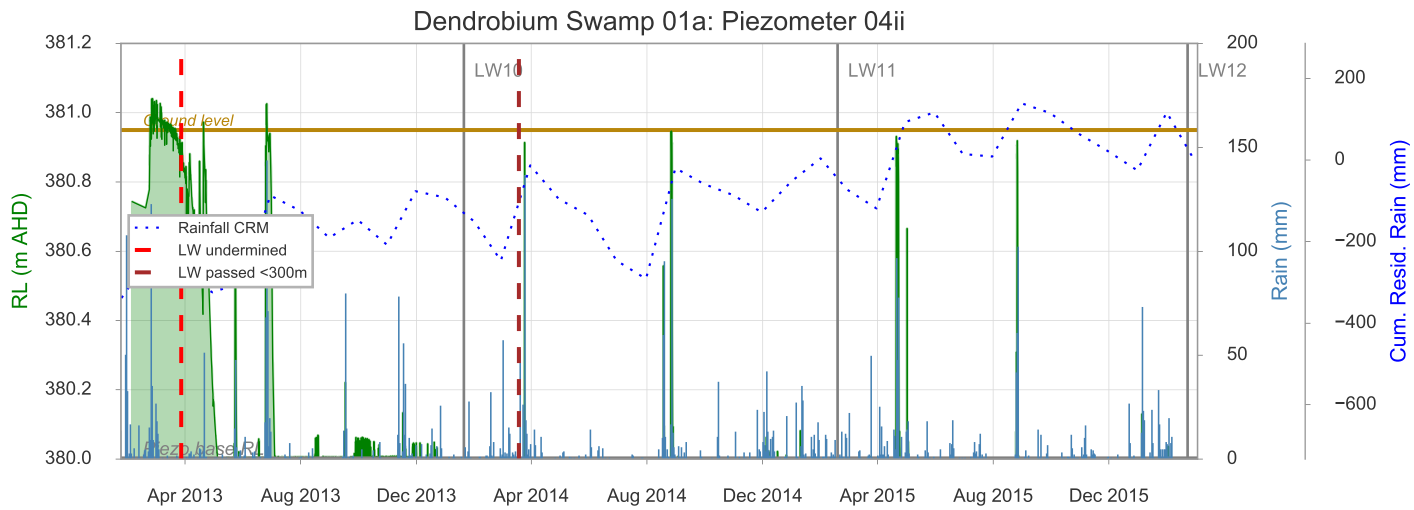
X:\HYDROSIM\DENDROBIUM\Reports\IWC004\Figures\DEN_Swamps_Hydrographs_2016_V13.pdf

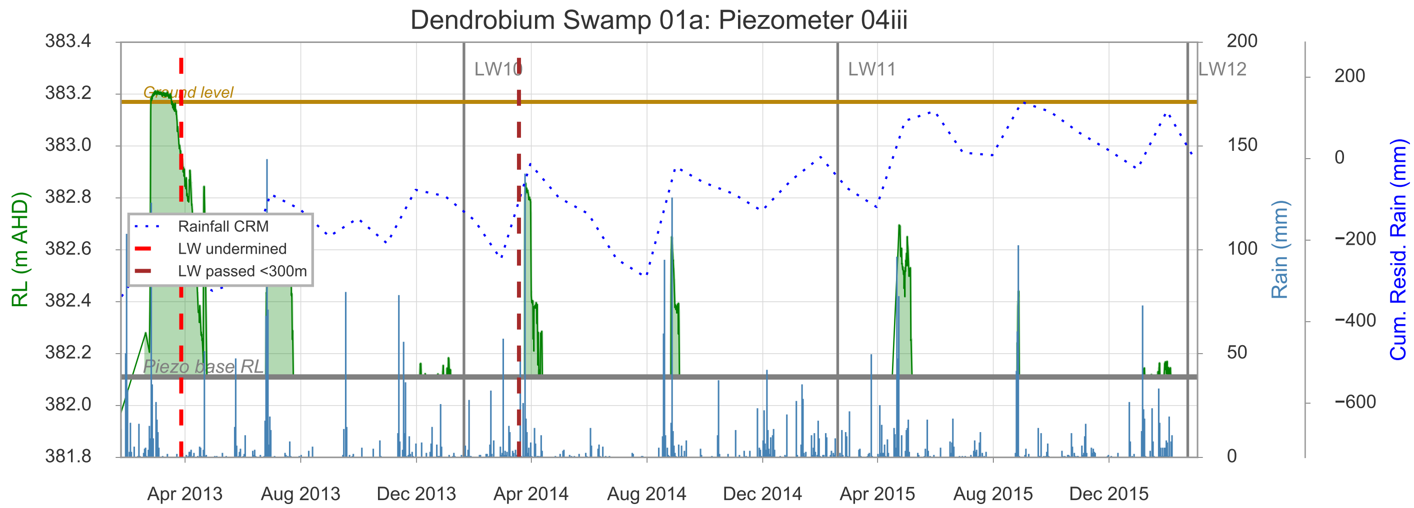

Dendrobium Swamp 01a: Piezometer 01
Ground level
Piezo base RL
LW9
LW10
LW11
LW12
Rainfall CRM
LW undermined
LW passed <300m
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
Aug 2012
Feb 2013
Aug 2013
Feb 2014
Aug 2014
Feb 2015
Aug 2015
Feb 2016

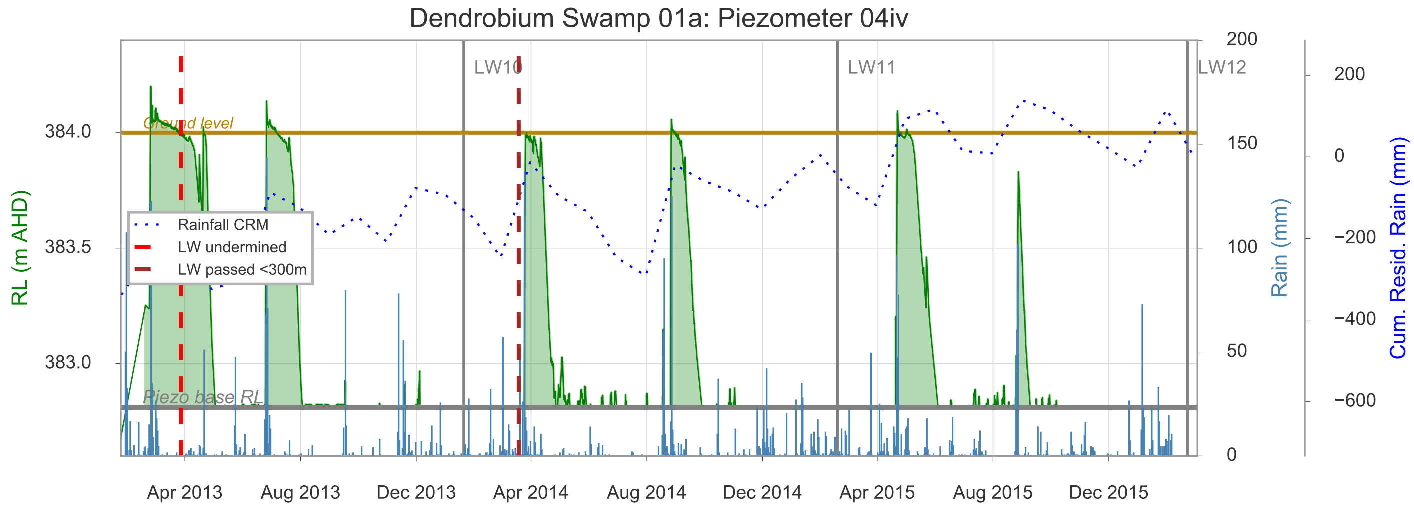

Dendrobium Swamp 01a: Piezometer 02
Ground level
Piezo base RL
LW9
LW10
LW11
LW12
Rainfall CRM
LW undermined
LW passed <300m
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
Aug 2012
Feb 2013
Aug 2013
Feb 2014
Aug 2014
Feb 2015
Aug 2015
Feb 2016

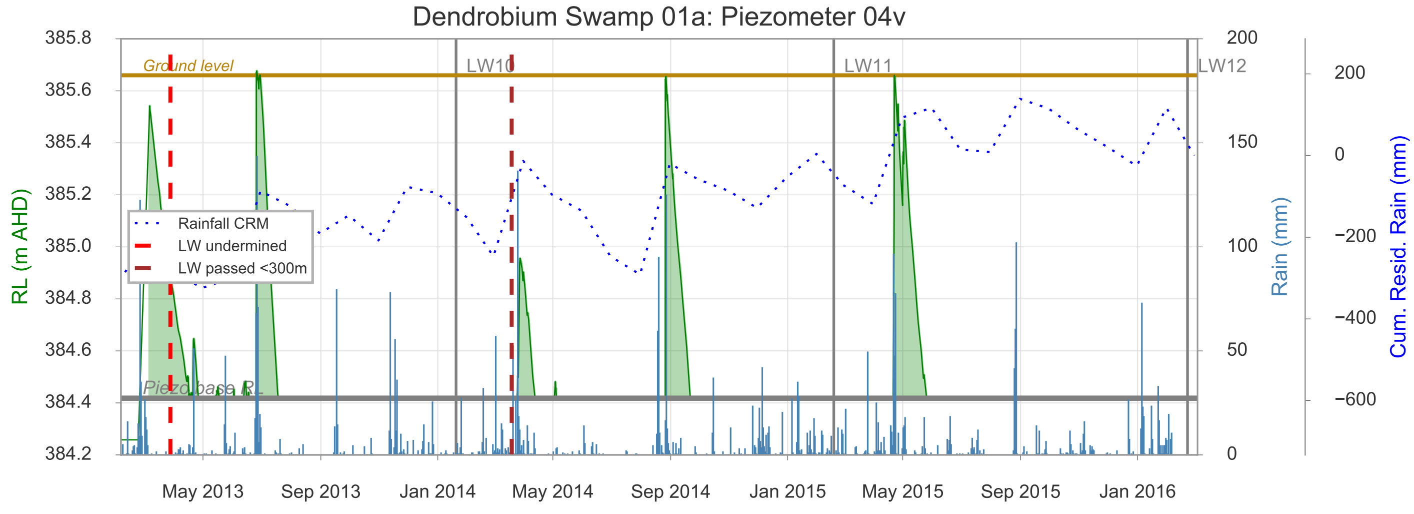

Dendrobium Swamp 01a: Piezometer 04
Ground level
Piezo base RL
LW9
LW10
LW11
LW12
Rainfall CRM
LW undermined
LW passed <300m
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
Aug 2012
Feb 2013
Aug 2013
Feb 2014
Aug 2014
Feb 2015
Aug 2015
Feb 2016

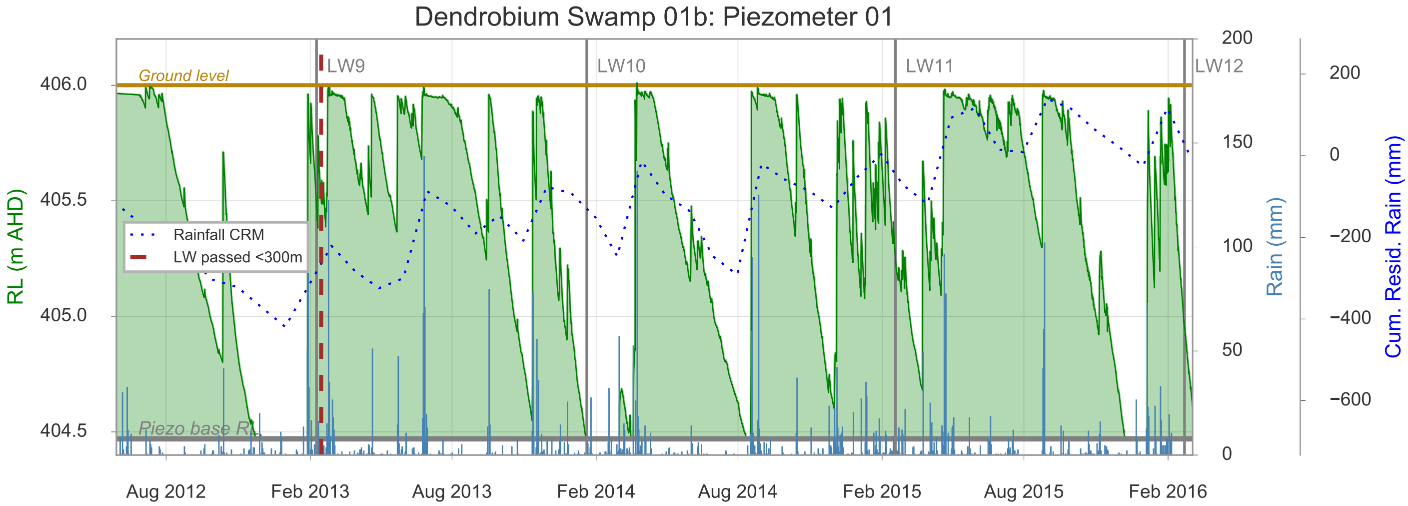

Dendrobium Swamp 01a: Piezometer 04i
Ground level
Piezo base RL
LW10
LW11
LW12
Rainfall CRM
LW undermined
LW passed <300m
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
May 2013
Sep 2013
Jan 2014
May 2014
Sep 2014
Jan 2015
May 2015
Sep 2015
Jan 2016


Dendrobium Swamp 01a: Piezometer 04ii
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
Ground level
Piezo base RL
LW10
LW11
LW12
Rainfall CRM
LW undermined
LW passed <300m
Apr 2013
Aug 2013
Dec 2013
Apr 2014
Aug 2014
Dec 2014
Apr 2015
Aug 2015
Dec 2015

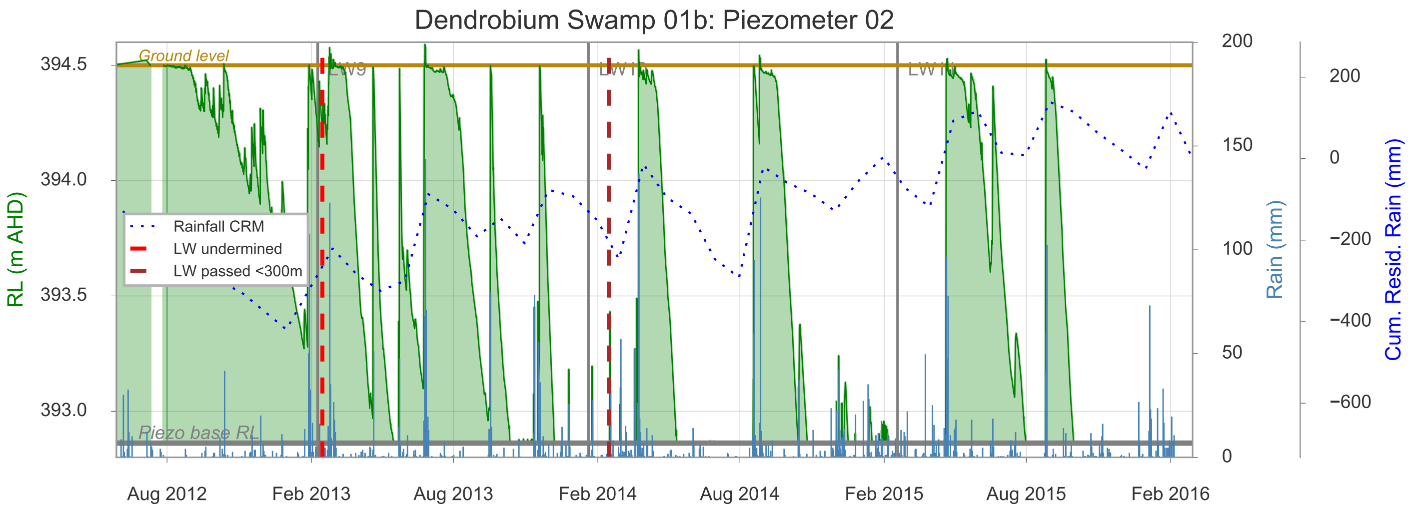

Dendrobium Swamp 01a: Piezometer 04iii
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
Ground level
Piezo base RL
LW10
LW11
LW12
Rainfall CRM
LW undermined
LW passed <300m
Apr 2013
Aug 2013
Dec 2013
Apr 2014
Aug 2014
Dec 2014
Apr 2015
Aug 2015
Dec 2015


Dendrobium Swamp 01a: Piezometer 04iv
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
Ground level
Piezo base RL
LW10
LW11
LW12
Rainfall CRM
LW undermined
LW passed <300m
Apr 2013
Aug 2013
Dec 2013
Apr 2014
Aug 2014
Dec 2014
Apr 2015
Aug 2015
Dec 2015

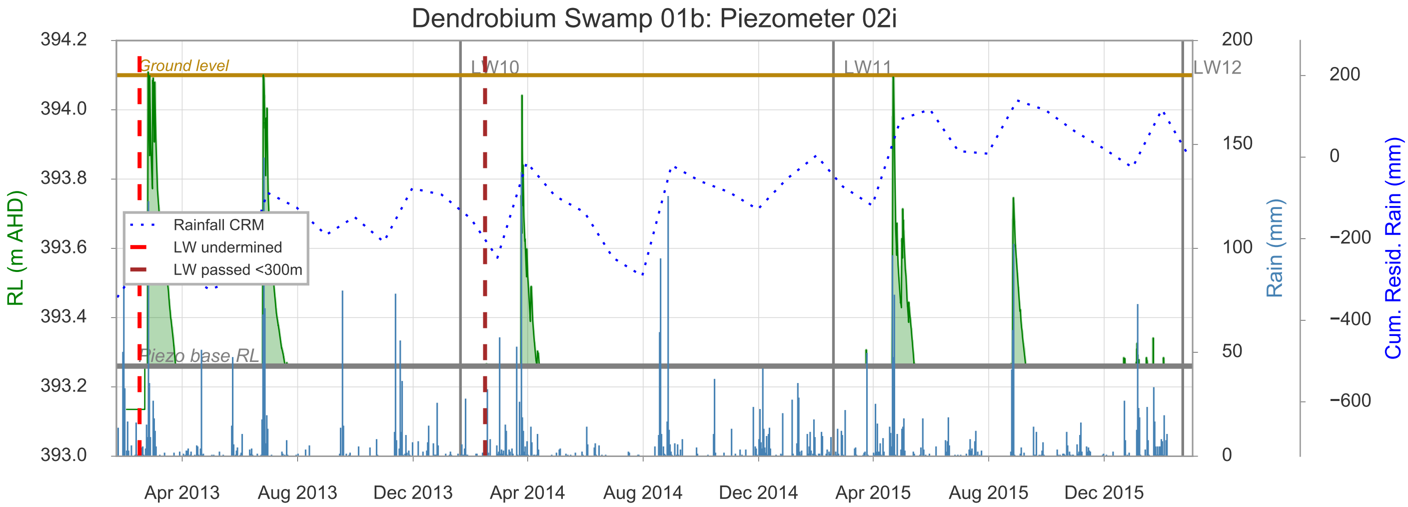

Dendrobium Swamp 01a: Piezometer 04v
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
Ground level
Piezo base RL
LW10
LW11
LW12
Rainfall CRM
LW undermined
LW passed <300m
May 2013
Sep 2013
Jan 2014
May 2014
Sep 2014
Jan 2015
May 2015
Sep 2015
Jan 2016



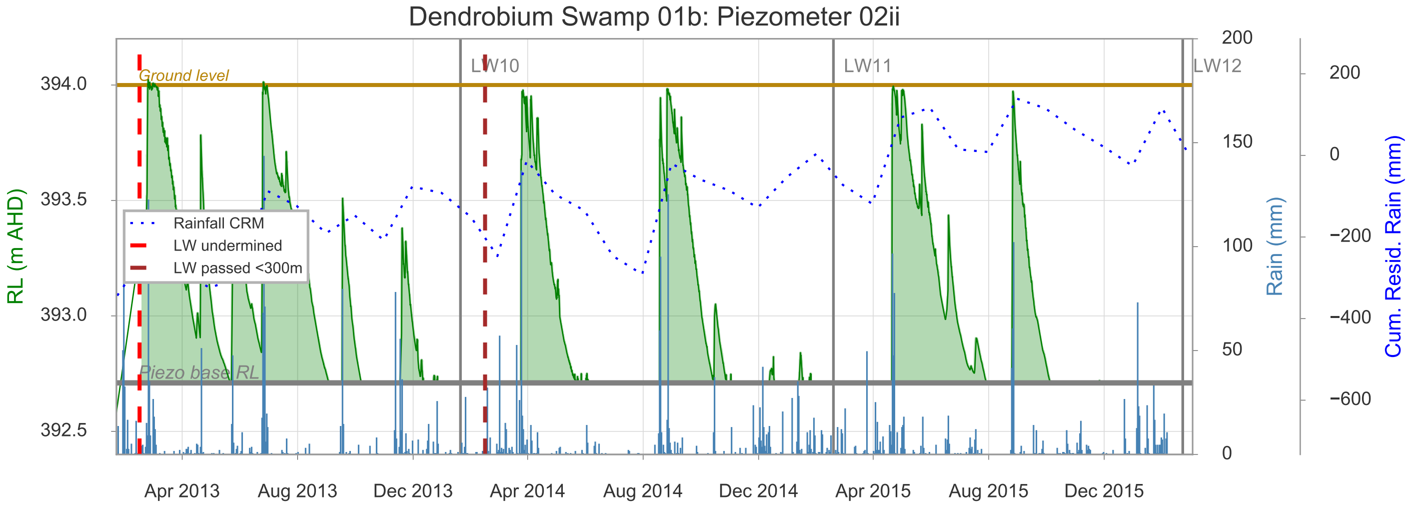
Dendrobium Swamp 01b: Piezometer 01
Ground level
Piezo base RL
LW9
LW10
LW11
LW12
Rainfall CRM
LW passed <300m
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
406.0
405.5
405.0
404.5
200
150
100
50
0
200
0
−200
−400
−600
Aug 2012
Feb 2013
Aug 2013
Feb 2014
Aug 2014
Feb 2015
Aug 2015
Feb 2016



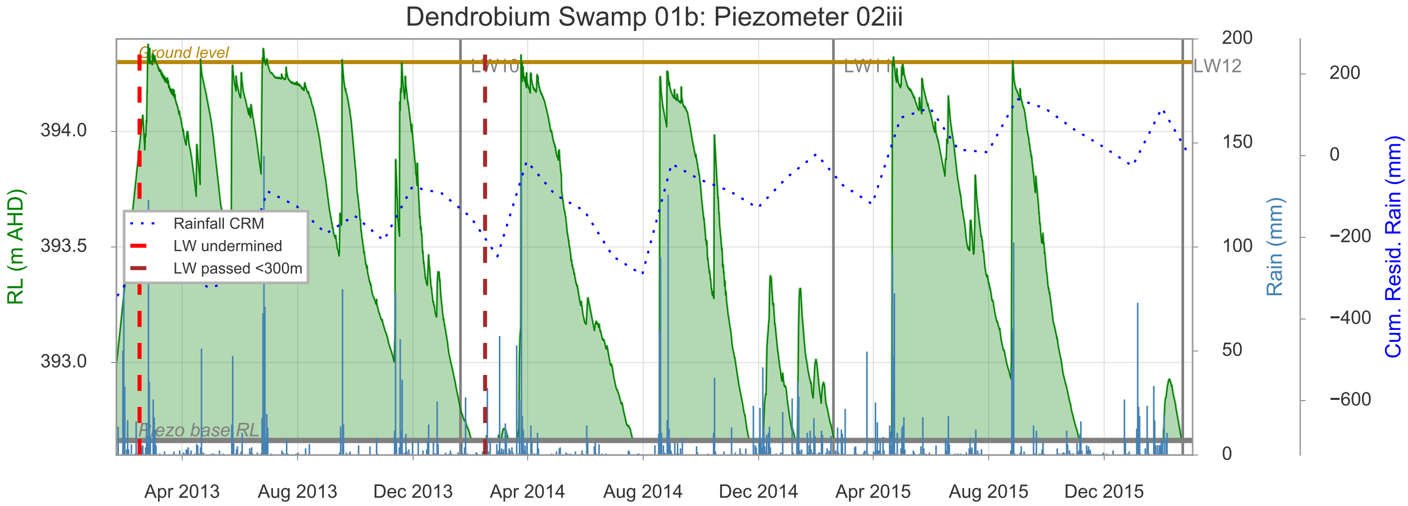
Dendrobium Swamp 01b: Piezometer 02
Ground level
Piezo base RL
LW9
Rainfall CRM
LW undermined
LW passed <300m
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
394.5
394.0
393.5
393.0
200
150
100
50
0
200
0
−200
−400
−600
Aug 2012
Feb 2013
Aug 2013
Feb 2014
Aug 2014
Feb 2015
Aug 2015
Feb 2016

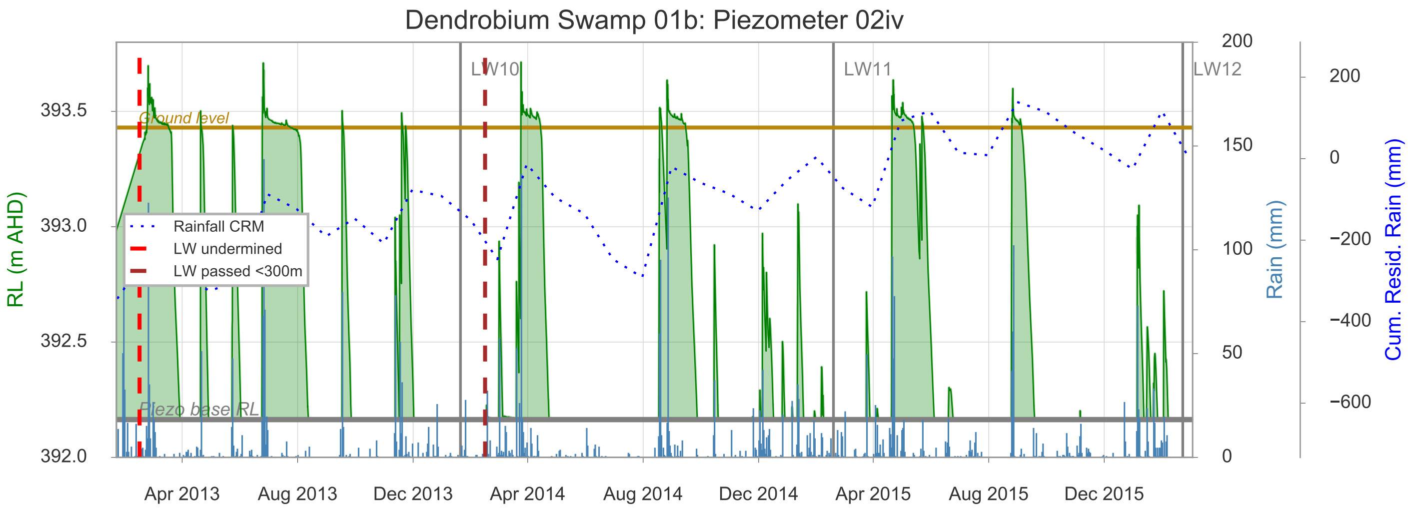


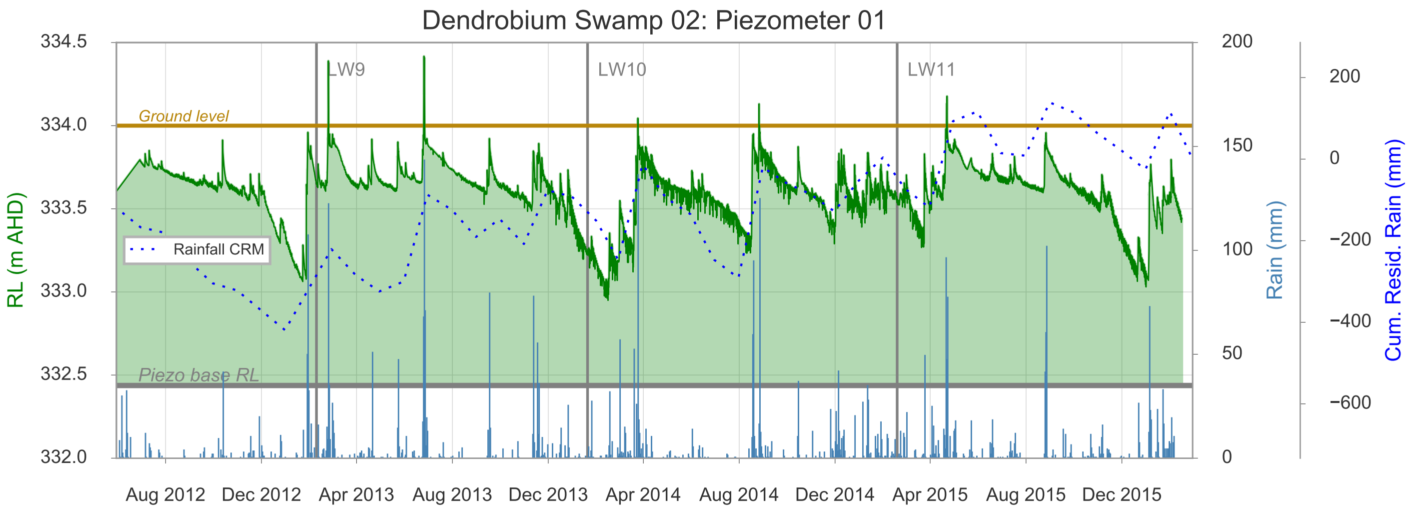
Dendrobium Swamp 01b: Piezometer 02i
Ground level
Piezo base RL
LW10
LW11
LW12
Rainfall CRM
LW undermined
LW passed <300m
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
394.2
394.0
393.8
393.6
393.4
393.2
393.0
200
150
100
50
0
200
0
−200
−400
−600
Apr 2013
Aug 2013
Dec 2013
Apr 2014
Aug 2014
Dec 2014
Apr 2015
Aug 2015
Dec 2015

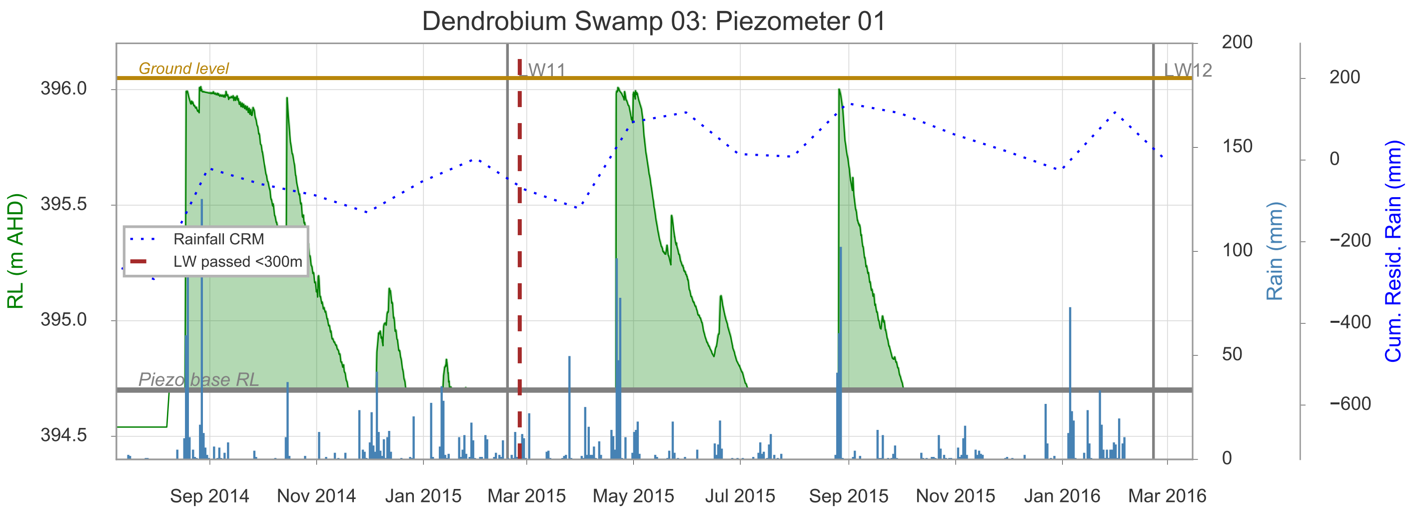


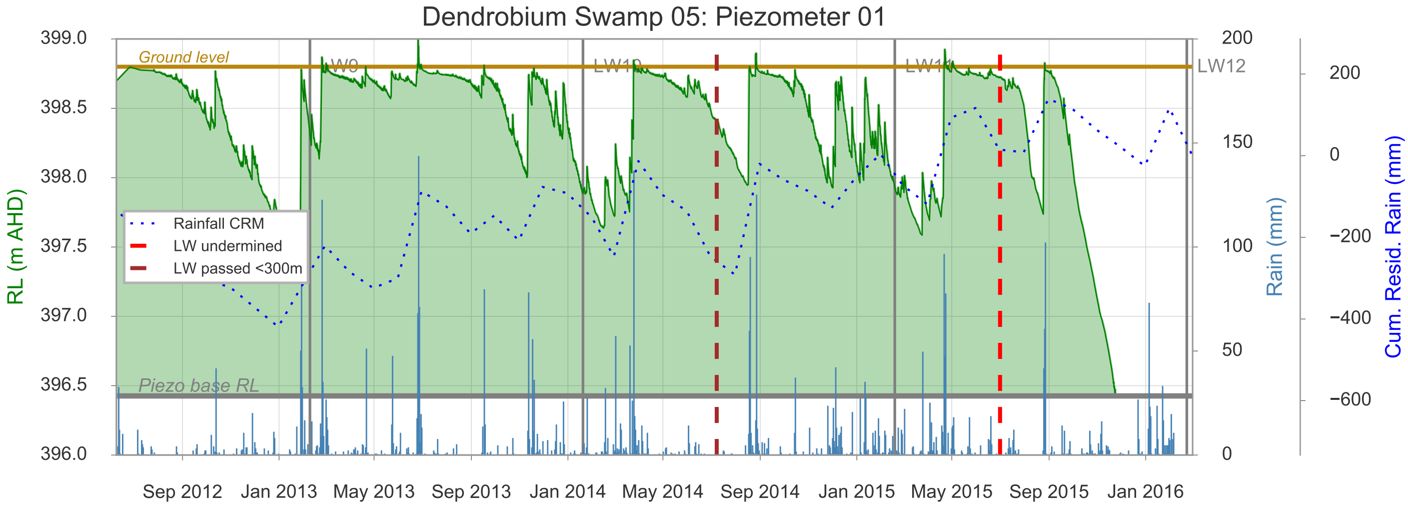
Dendrobium Swamp 01b: Piezometer 02ii
Ground level
Piezo base RL
LW10
LW11
LW12
Rainfall CRM
LW undermined
LW passed <300m
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
394.0
393.5
393.0
392.5
200
150
100
50
0
200
0
−200
−400
−600
Apr 2013
Aug 2013
Dec 2013
Apr 2014
Aug 2014
Dec 2014
Apr 2015
Aug 2015
Dec 2015

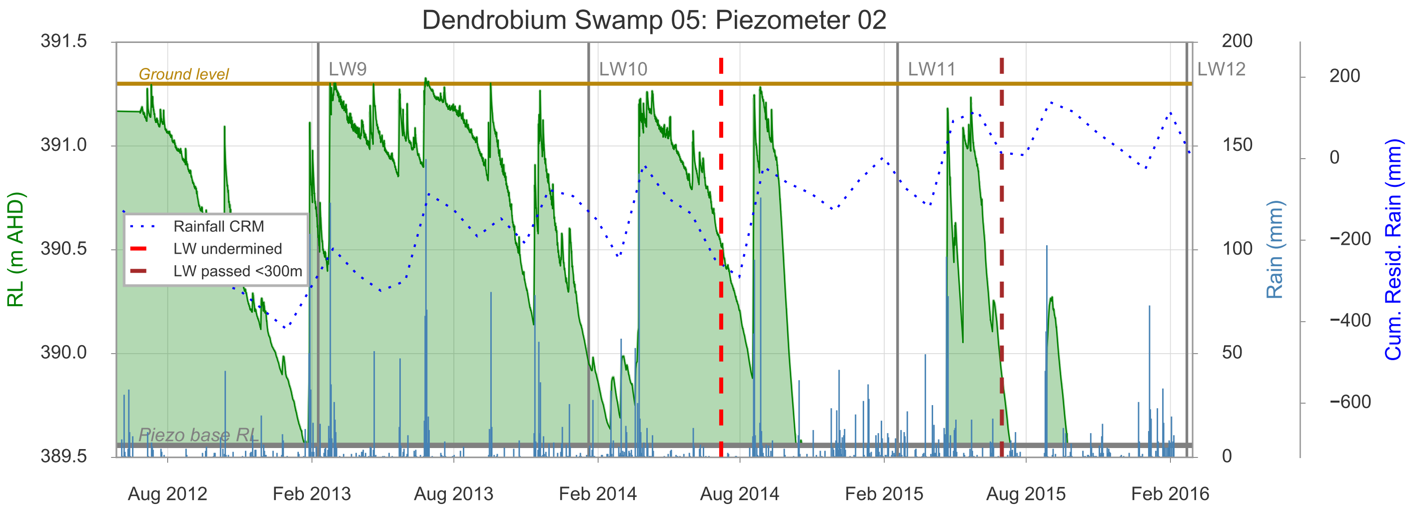

Dendrobium Swamp 01b: Piezometer 02iii
Ground level
LW10
LW11
LW12
Piezo base RL
Rainfall CRM
LW undermined
LW passed <300m
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
394.0
393.5
393.0
200
150
100
50
0
200
0
−200
−400
−600
Apr 2013
Aug 2013
Dec 2013
Apr 2014
Aug 2014
Dec 2014
Apr 2015
Aug 2015
Dec 2015

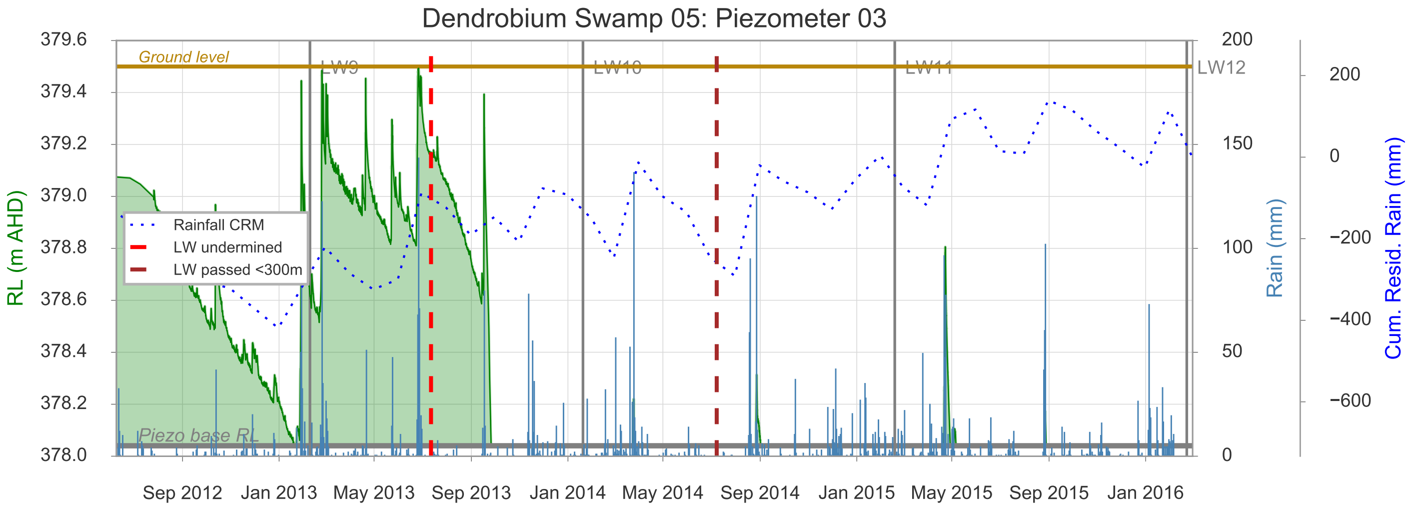

Dendrobium Swamp 01b: Piezometer 02iv
Ground level
LW10
LW11
LW12
Piezo base RL
Rainfall CRM
LW undermined
LW passed <300m
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
393.5
393.0
392.5
392.0
200
150
100
50
0
200
0
−200
−400
−600
Apr 2013
Aug 2013
Dec 2013
Apr 2014
Aug 2014
Dec 2014
Apr 2015
Aug 2015
Dec 2015

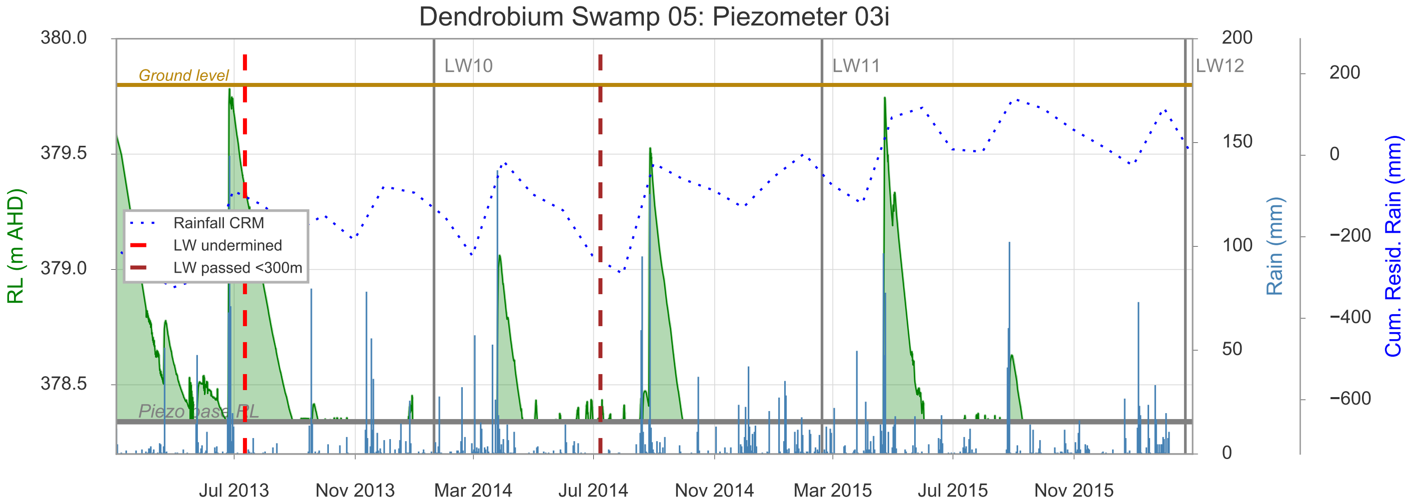

Dendrobium Swamp 02: Piezometer 01
Ground level
LW9
LW10
LW11
Piezo base RL
Rainfall CRM
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
334.5
334.0
333.5
333.0
332.5
332.0
200
150
100
50
0
200
0
−200
−400
−600
Aug 2012
Dec 2012
Apr 2013
Aug 2013
Dec 2013
Apr 2014
Aug 2014
Dec 2014
Apr 2015
Aug 2015
Dec 2015


Dendrobium Swamp 03: Piezometer 01
Ground level
LW11
LW12
Piezo base RL
Rainfall CRM
LW passed <300m
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
396.0
395.5
395.0
394.5
200
150
100
50
0
200
0
−200
−400
−600
Sep 2014
Nov 2014
Jan 2015
Mar 2015
May 2015
Jul 2015
Sep 2015
Nov 2015
Jan 2016
Mar 2016

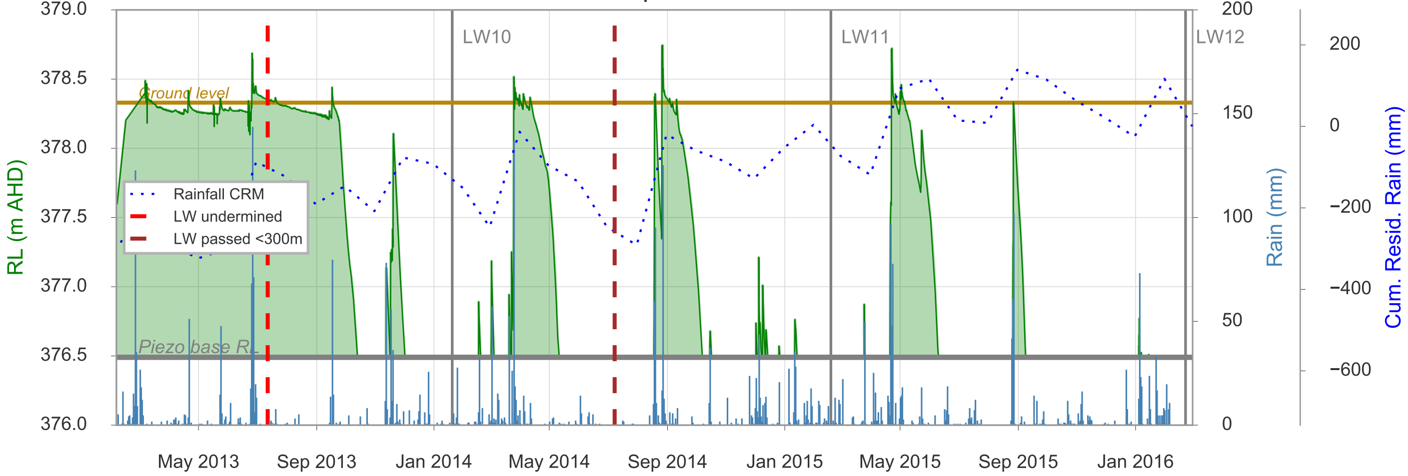

Dendrobium Swamp 05: Piezometer 01
Ground level
Piezo base RL
LW9
LW10
LW11
LW12
Rainfall CRM
LW undermined
LW passed <300m
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
399.0
398.5
398.0
397.5
397.0
396.5
396.0
200
150
100
50
0
-200
-400
-600
Sep 2012
Jan 2013
May 2013
Sep 2013
Jan 2014
May 2014
Sep 2014
Jan 2015
May 2015
Sep 2015
Jan 2016


Dendrobium Swamp 05: Piezometer 02
Ground level
Piezo base RL
LW9
LW10
LW11
LW12
Rainfall CRM
LW undermined
LW passed <300m
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
391.5
391.0
390.5
390.0
389.5
200
150
100
50
0
-200
-400
-600
Aug 2012
Feb 2013
Aug 2013
Feb 2014
Aug 2014
Feb 2015
Aug 2015
Feb 2016

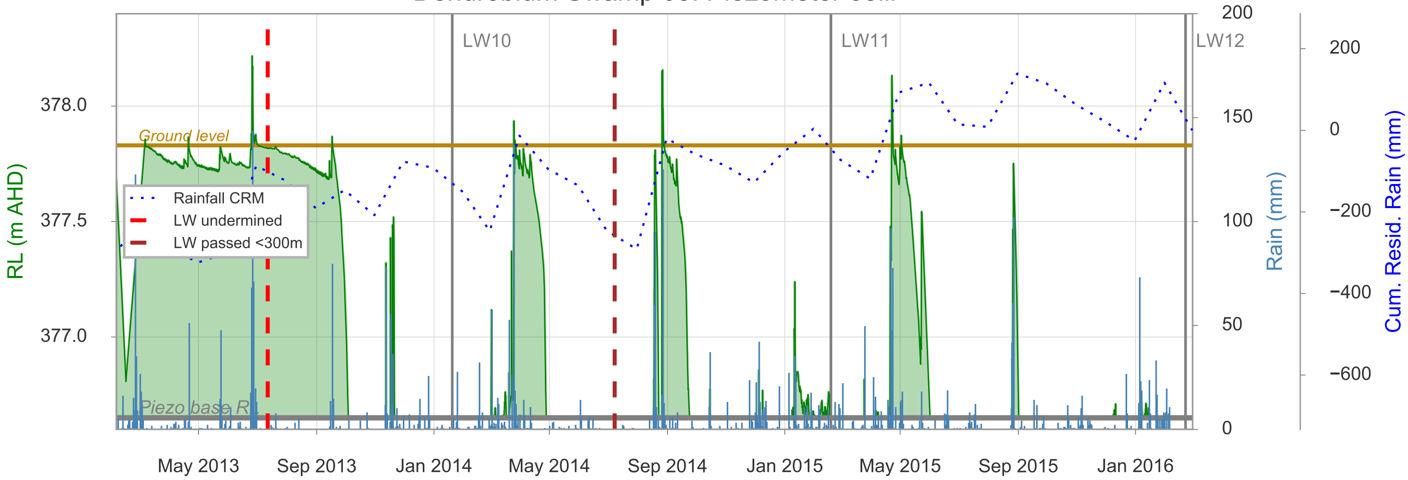

Dendrobium Swamp 05: Piezometer 03
Ground level
Piezo base RL
LW9
LW10
LW11
LW12
Rainfall CRM
LW undermined
LW passed <300m
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
379.6
379.4
379.2
379.0
378.8
378.6
378.4
378.2
378.0
200
150
100
50
0
-200
-400
-600
Sep 2012
Jan 2013
May 2013
Sep 2013
Jan 2014
May 2014
Sep 2014
Jan 2015
May 2015
Sep 2015
Jan 2016


Dendrobium Swamp 05: Piezometer 03i
Ground level
Piezo base RL
LW10
LW11
LW12
Rainfall CRM
LW undermined
LW passed <300m
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
380.0
379.5
379.0
378.5
200
150
100
50
0
-200
-400
-600
Jul 2013
Nov 2013
Mar 2014
Jul 2014
Nov 2014
Mar 2015
Jul 2015
Nov 2015

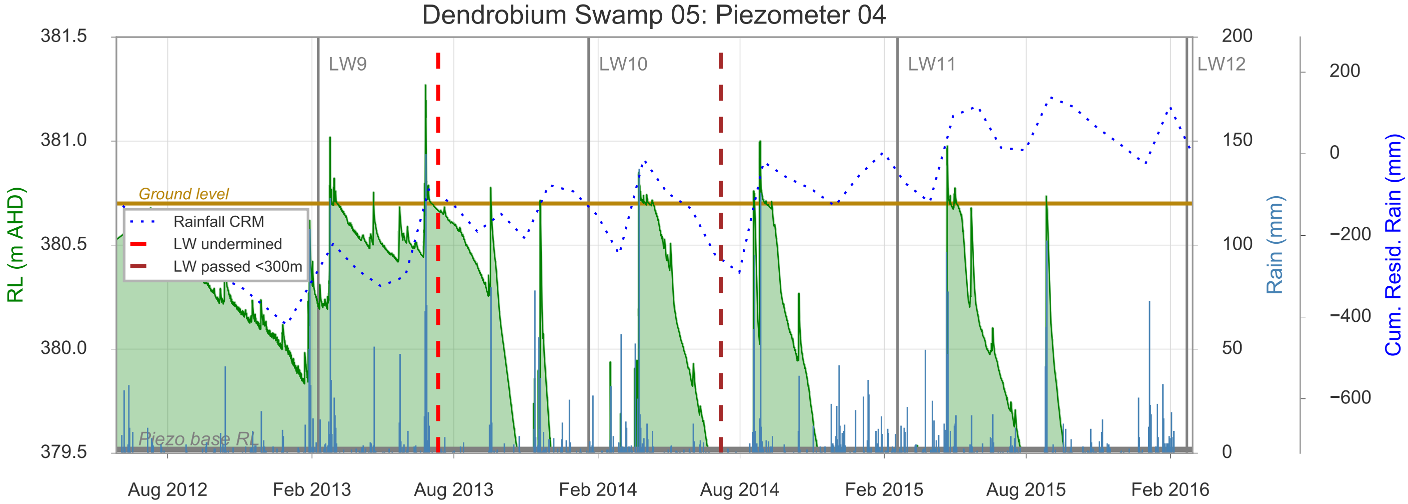
Dendrobium Swamp 05: Piezometer 03ii



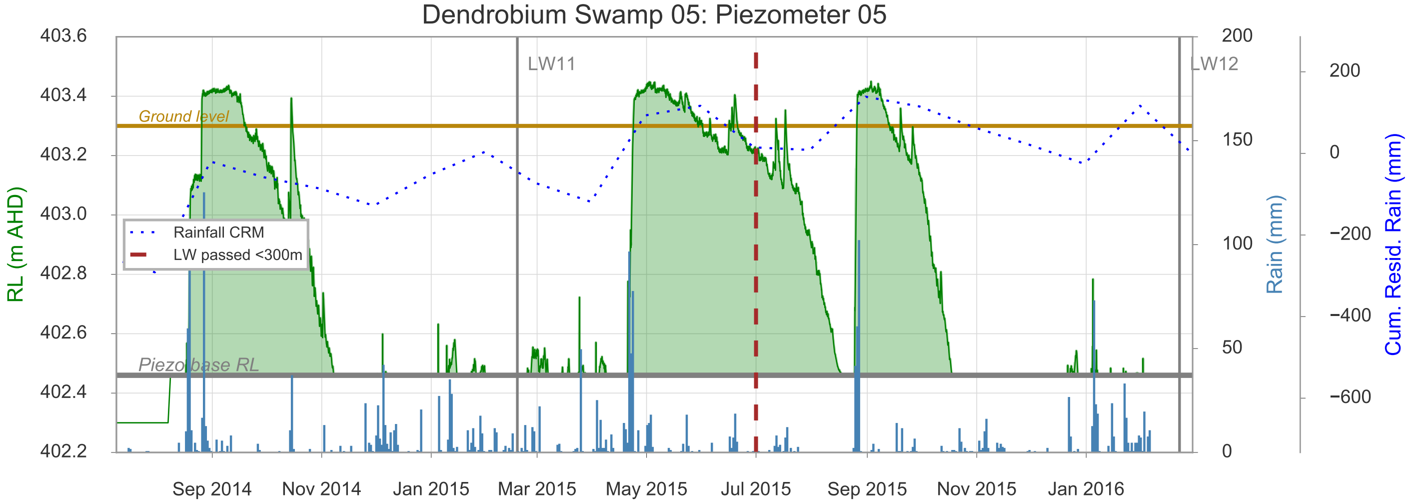
Dendrobium Swamp 05: Piezometer 03iii



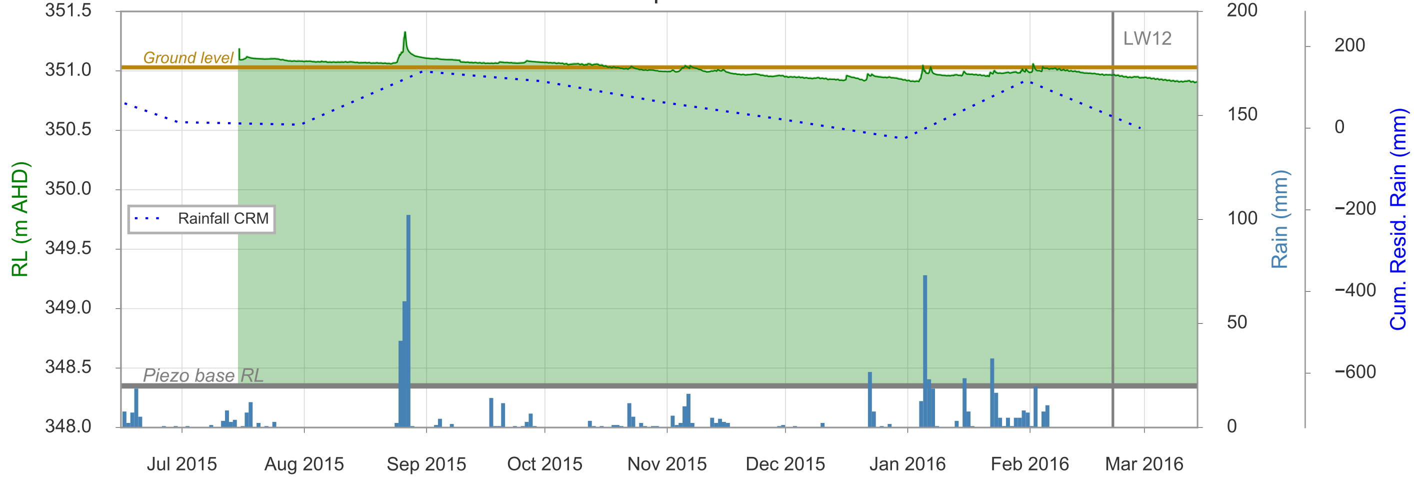
Dendrobium Swamp 05: Piezometer 04



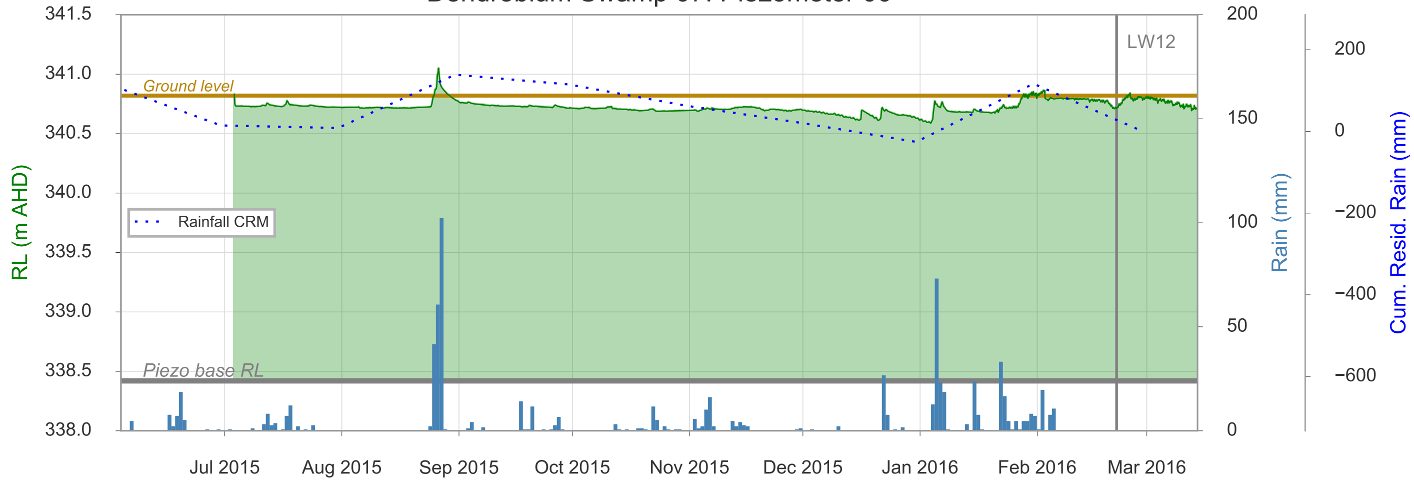
Dendrobium Swamp 05: Piezometer 05



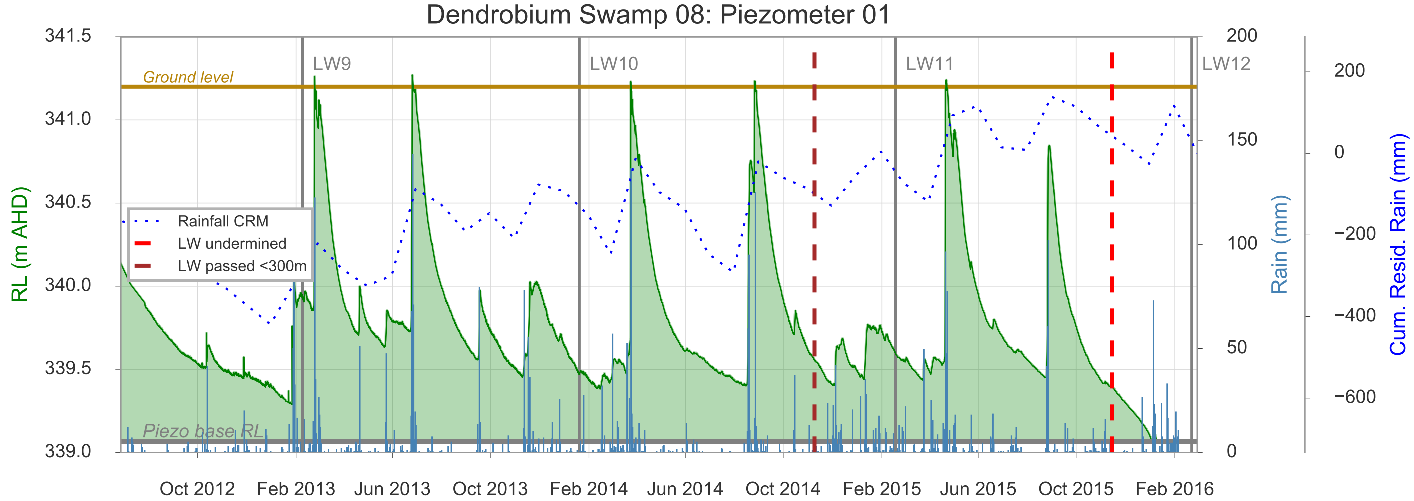
Dendrobium Swamp 07: Piezometer 05



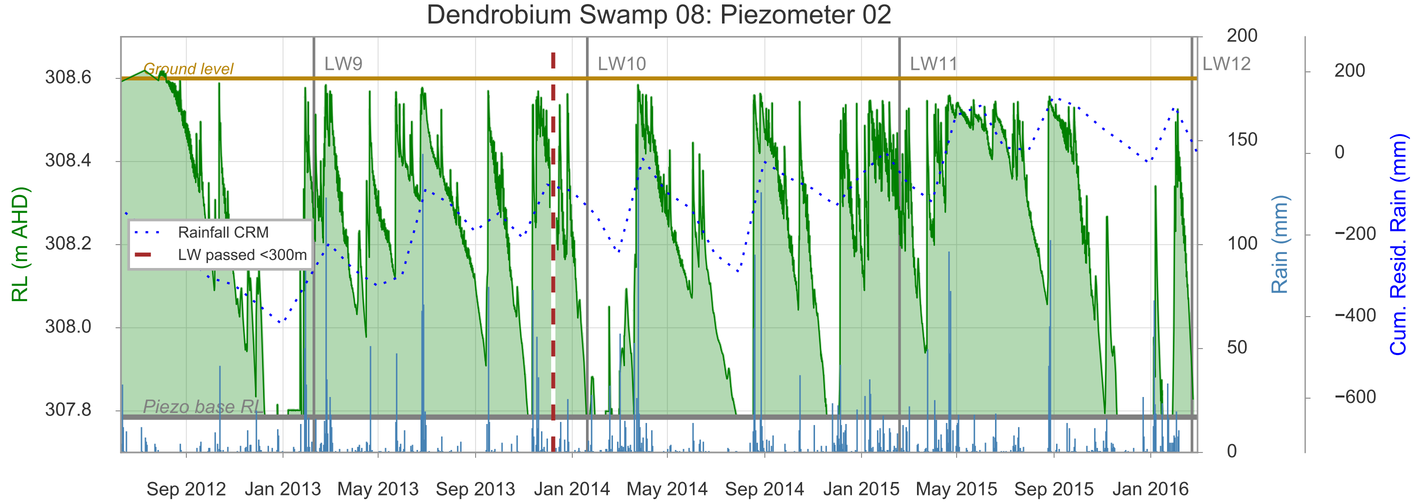
Dendrobium Swamp 07: Piezometer 06

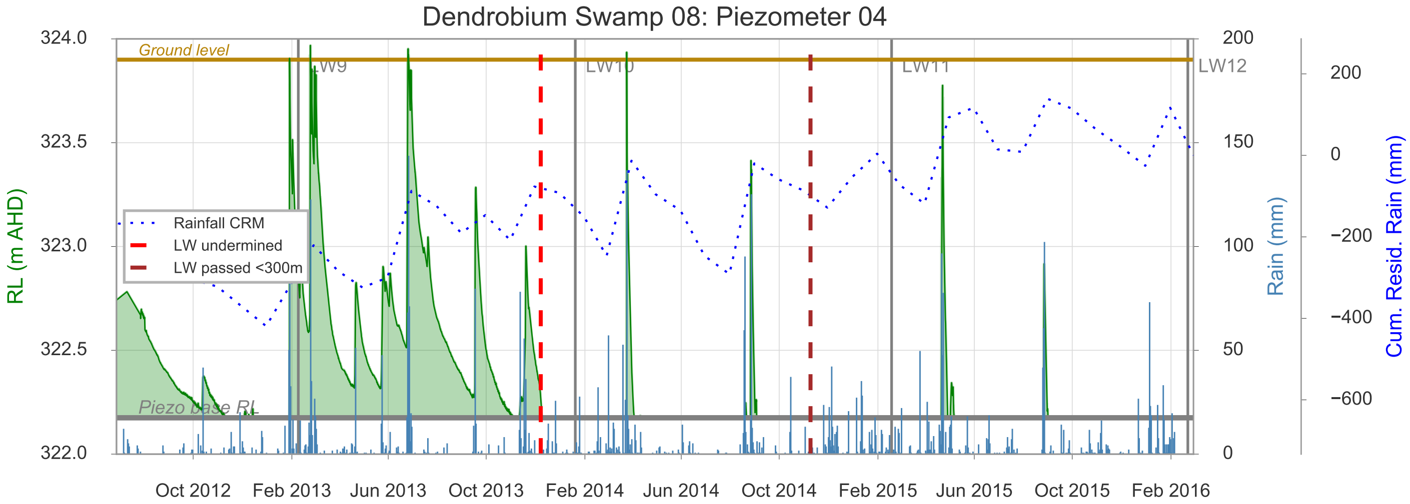


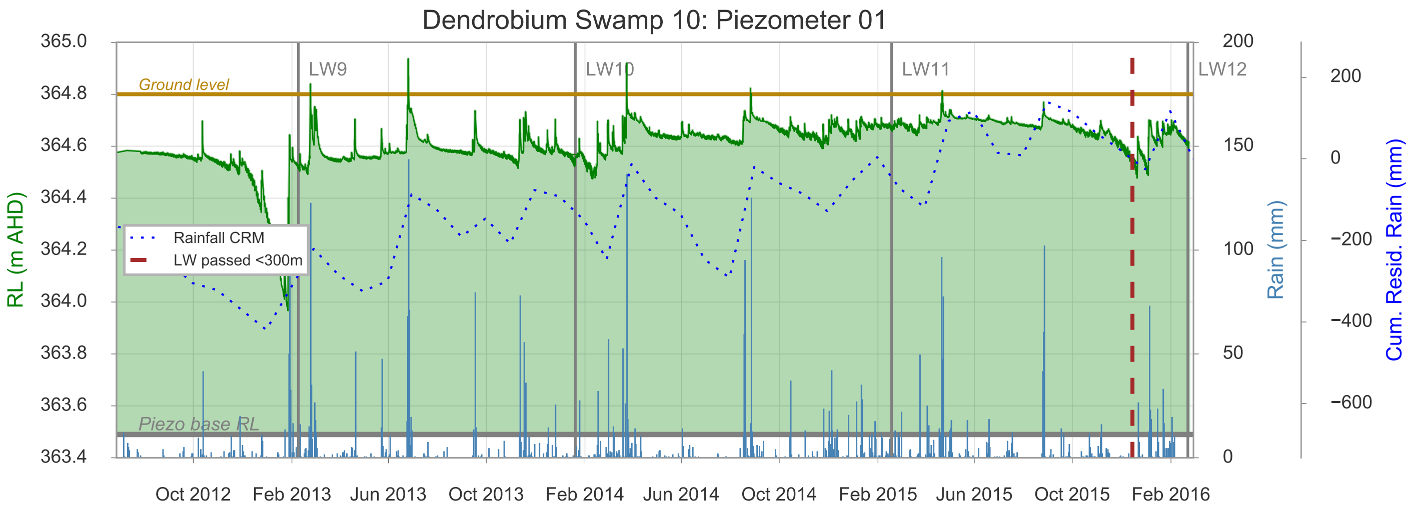
Dendrobium Swamp 08: Piezometer 01

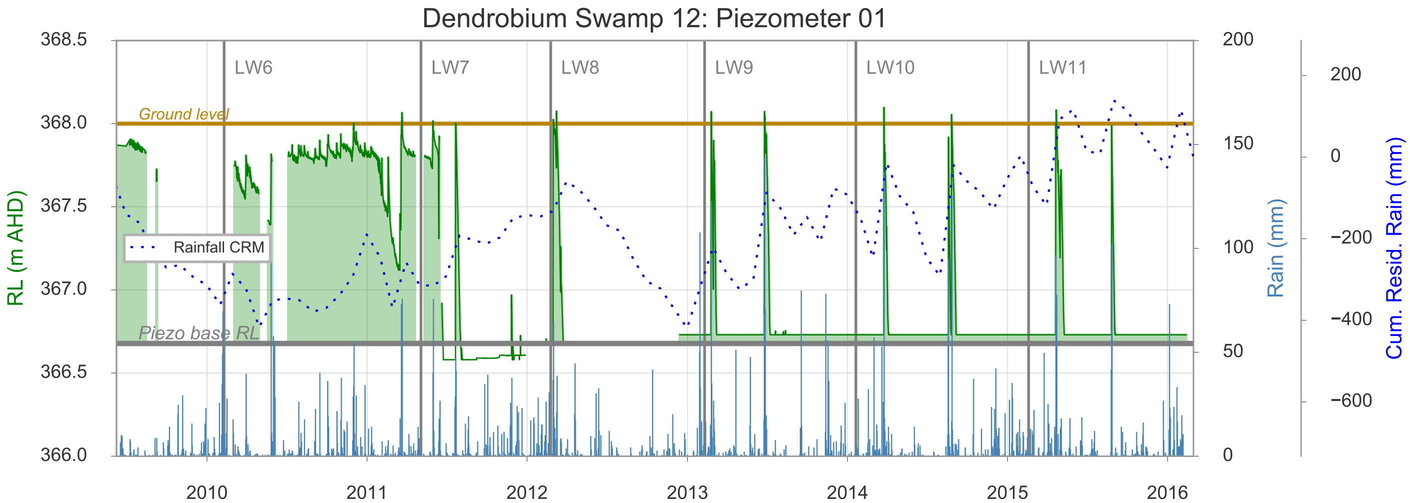


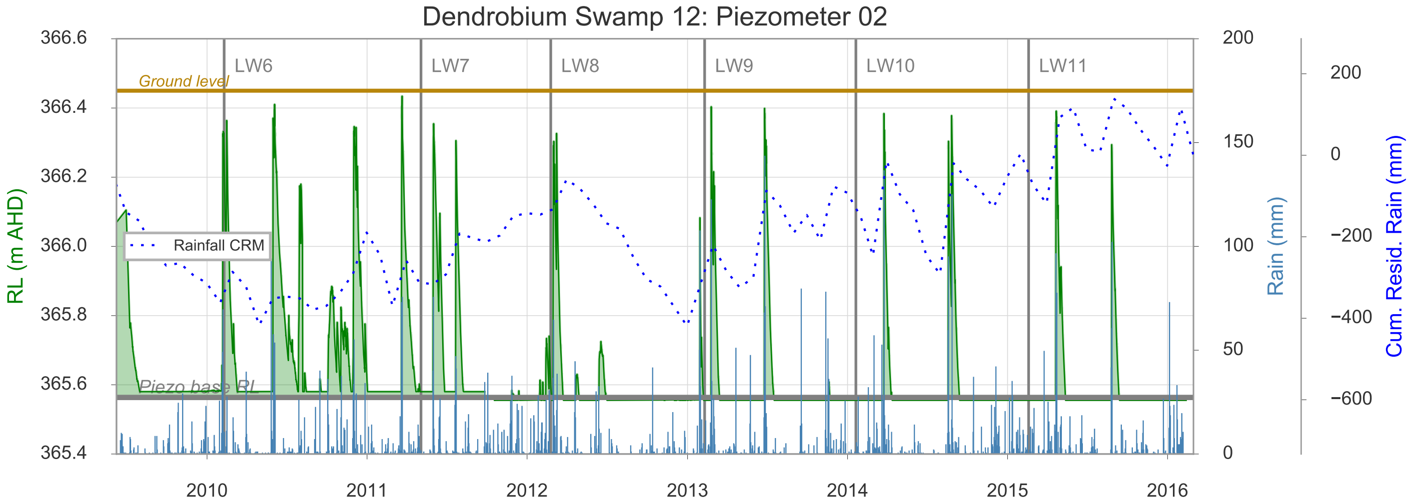
Dendrobium Swamp 08: Piezometer 02

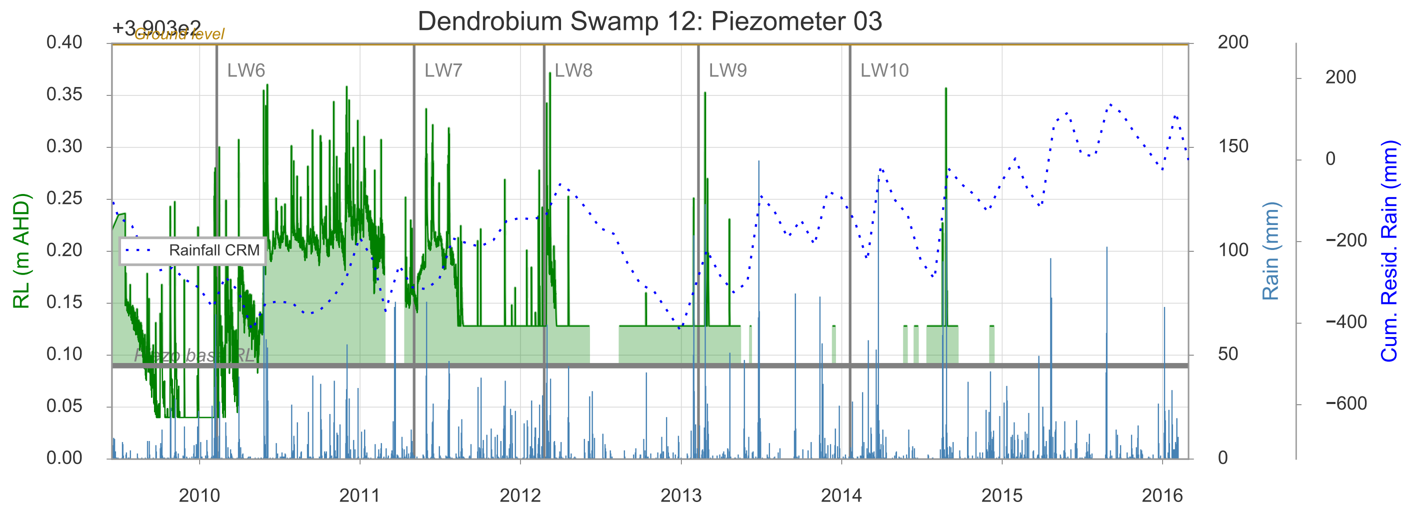


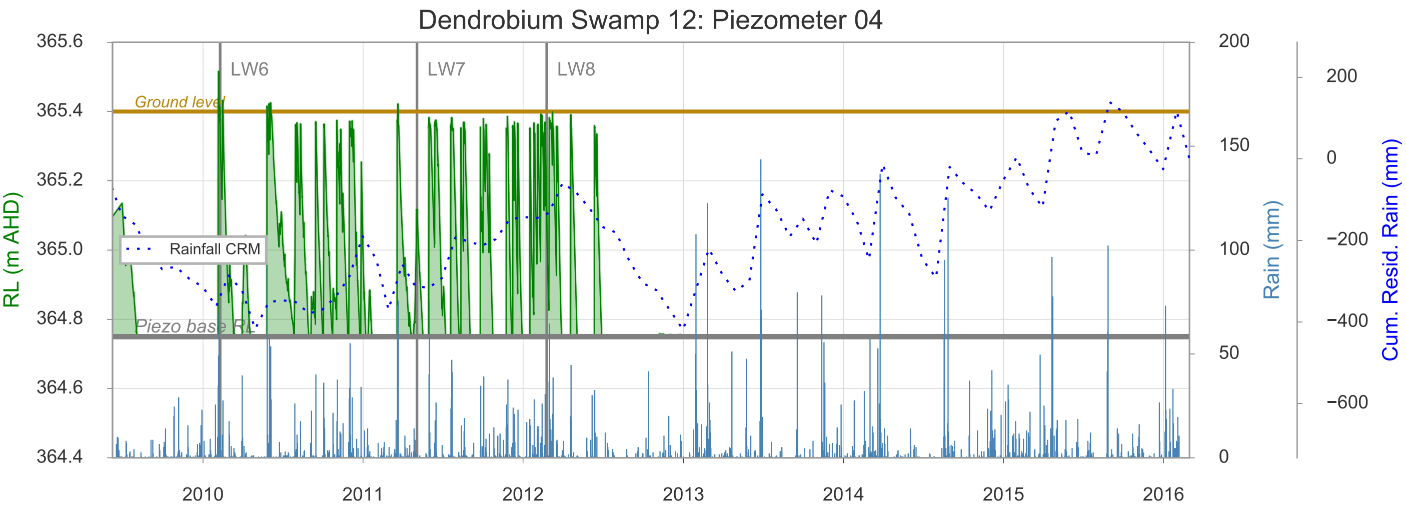

Dendrobium Swamp 08: Piezometer 04
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
Ground level
Piezo base RL
LW9
LW10
LW11
LW12
Rainfall CRM
LW undermined
LW passed <300m
Oct 2012
Feb 2013
Jun 2013
Oct 2013
Feb 2014
Jun 2014
Oct 2014
Feb 2015
Jun 2015
Oct 2015
Feb 2016

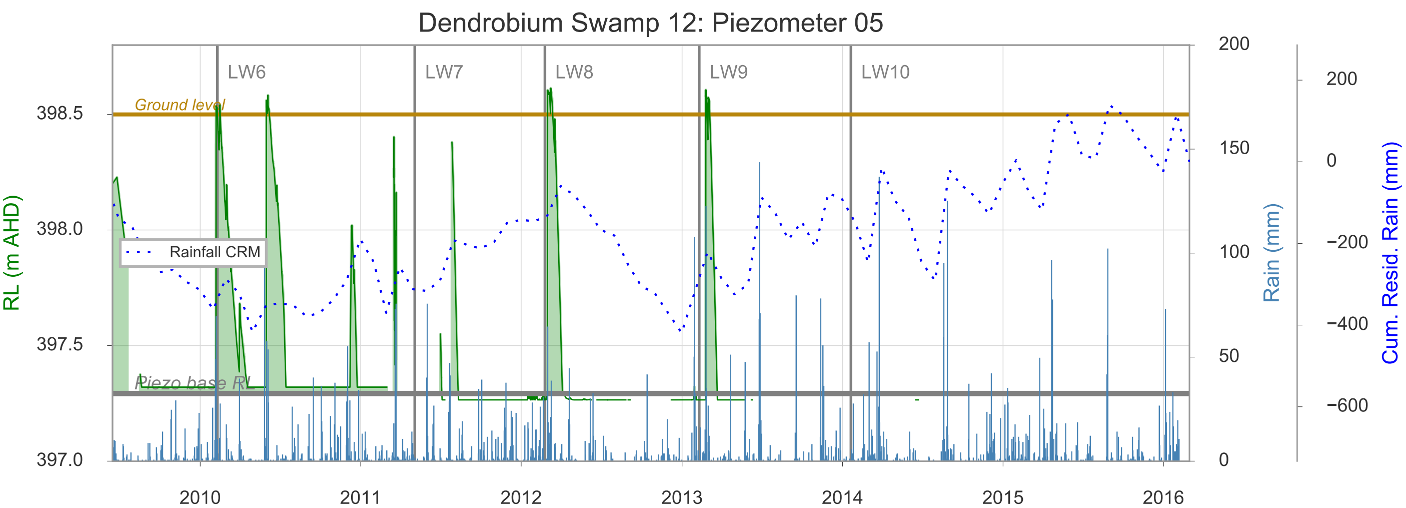

Dendrobium Swamp 10: Piezometer 01
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
Ground level
Piezo base RL
LW9
LW10
LW11
LW12
Rainfall CRM
LW passed <300m
Oct 2012
Feb 2013
Jun 2013
Oct 2013
Feb 2014
Jun 2014
Oct 2014
Feb 2015
Jun 2015
Oct 2015
Feb 2016

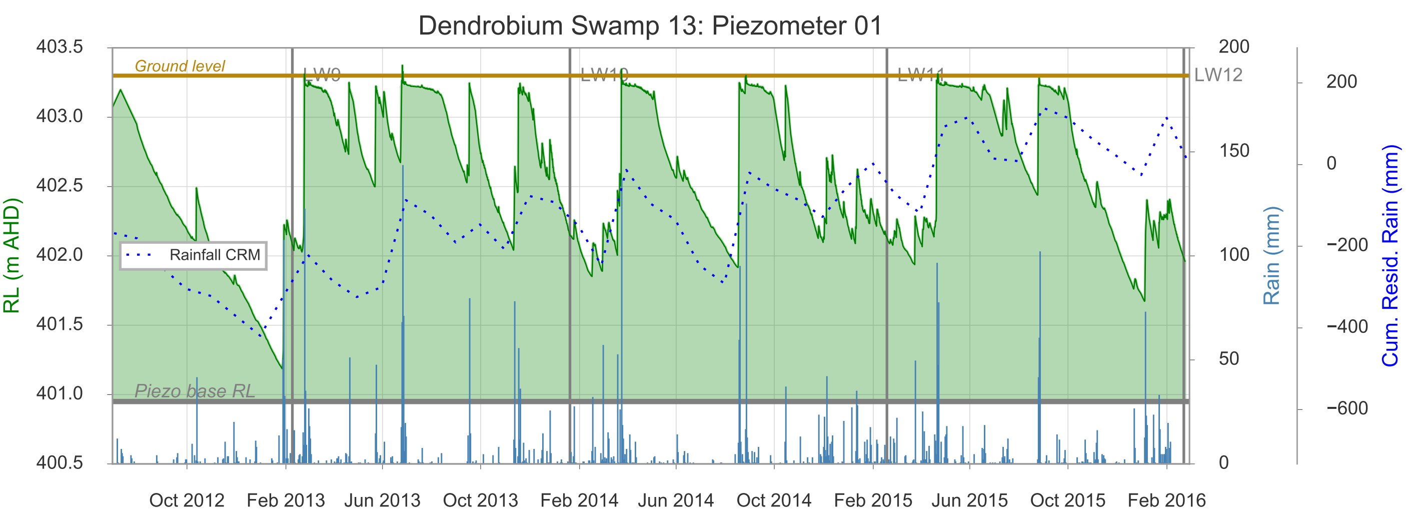

Dendrobium Swamp 12: Piezometer 01
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
Ground level
Piezo base RL
LW6
LW7
LW8
LW9
LW10
LW11
Rainfall CRM
2010
2011
2012
2013
2014
2015
2016

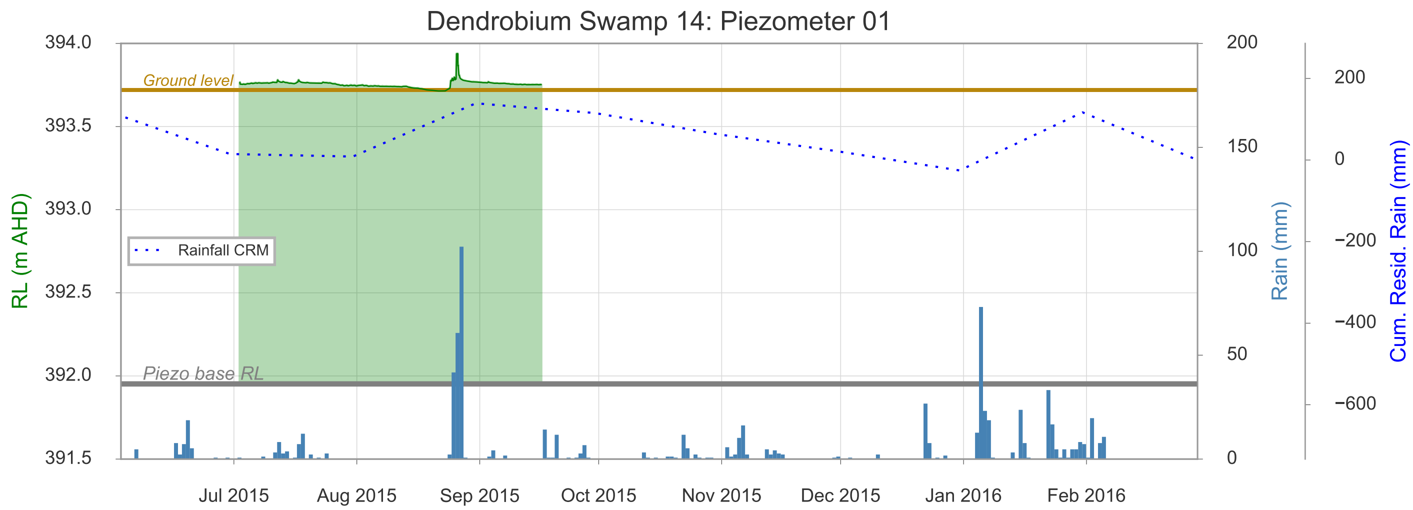

Dendrobium Swamp 12: Piezometer 02
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
Ground level
Piezo base RL
LW6
LW7
LW8
LW9
LW10
LW11
Rainfall CRM
2010
2011
2012
2013
2014
2015
2016

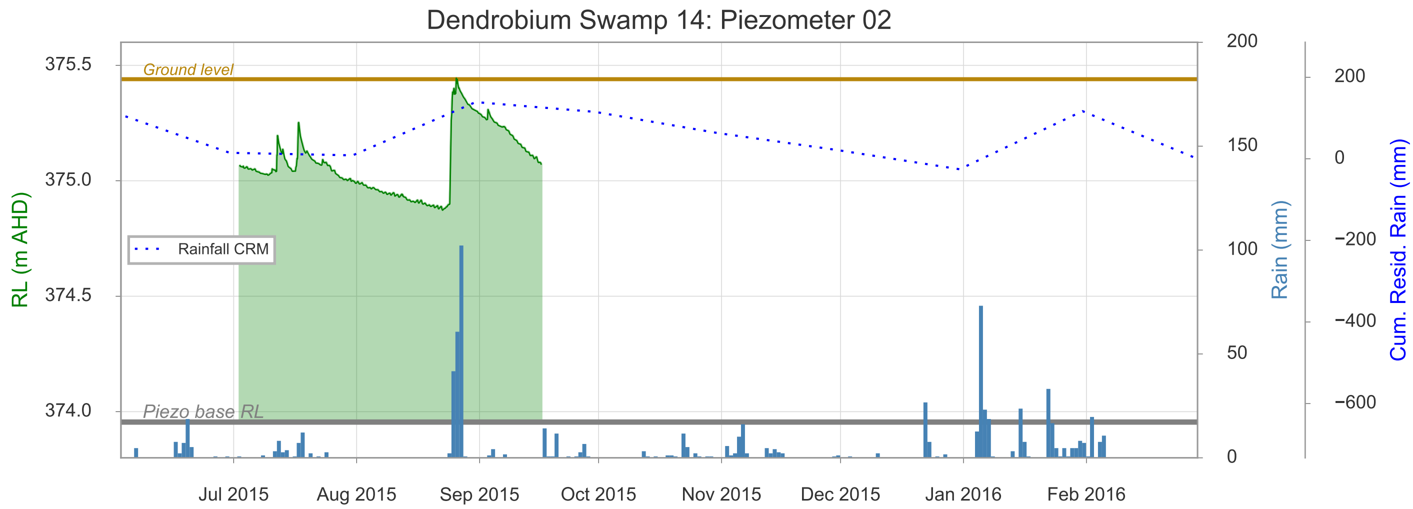

Dendrobium Swamp 12: Piezometer 03
+3.903e2
Ground level
Piezo base RL
LW6
LW7
LW8
LW9
LW10
Rainfall CRM
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
200
150
100
50
0
200
0
−200
−400
−600
2010
2011
2012
2013
2014
2015
2016

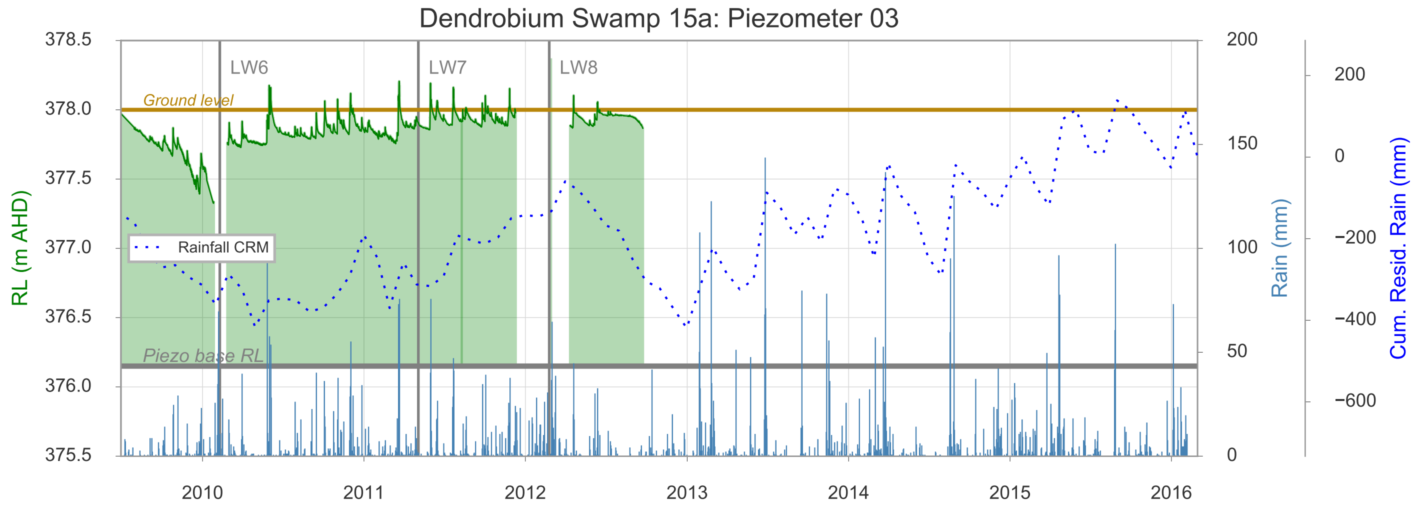

Dendrobium Swamp 12: Piezometer 04
Ground level
Piezo base RL
LW6
LW7
LW8
Rainfall CRM
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
365.6
365.4
365.2
365.0
364.8
364.6
364.4
200
150
100
50
0
200
0
−200
−400
−600
2010
2011
2012
2013
2014
2015
2016

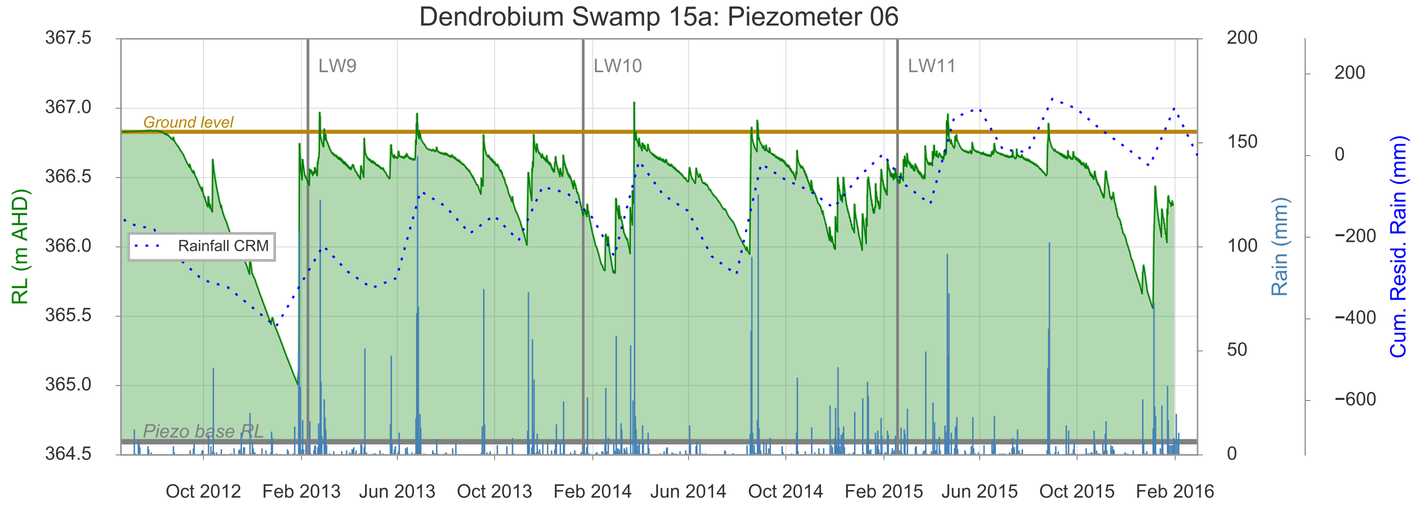

Dendrobium Swamp 12: Piezometer 05
Ground level
Piezo base RL
LW6
LW7
LW8
LW9
LW10
Rainfall CRM
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
398.5
398.0
397.5
397.0
200
150
100
50
0
200
0
−200
−400
−600
2010
2011
2012
2013
2014
2015
2016

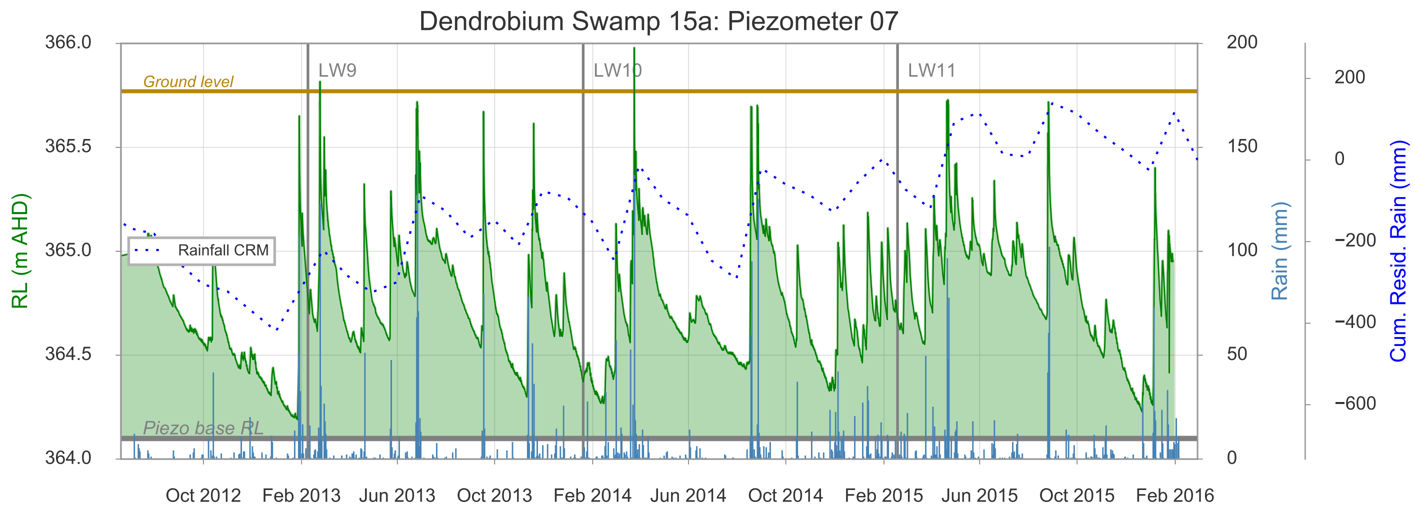

Dendrobium Swamp 13: Piezometer 01
Ground level
Piezo base RL
LW9
LW10
LW11
LW12
Rainfall CRM
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
403.5
403.0
402.5
402.0
401.5
401.0
400.5
200
150
100
50
0
200
0
−200
−400
−600
Oct 2012
Feb 2013
Jun 2013
Oct 2013
Feb 2014
Jun 2014
Oct 2014
Feb 2015
Jun 2015
Oct 2015
Feb 2016

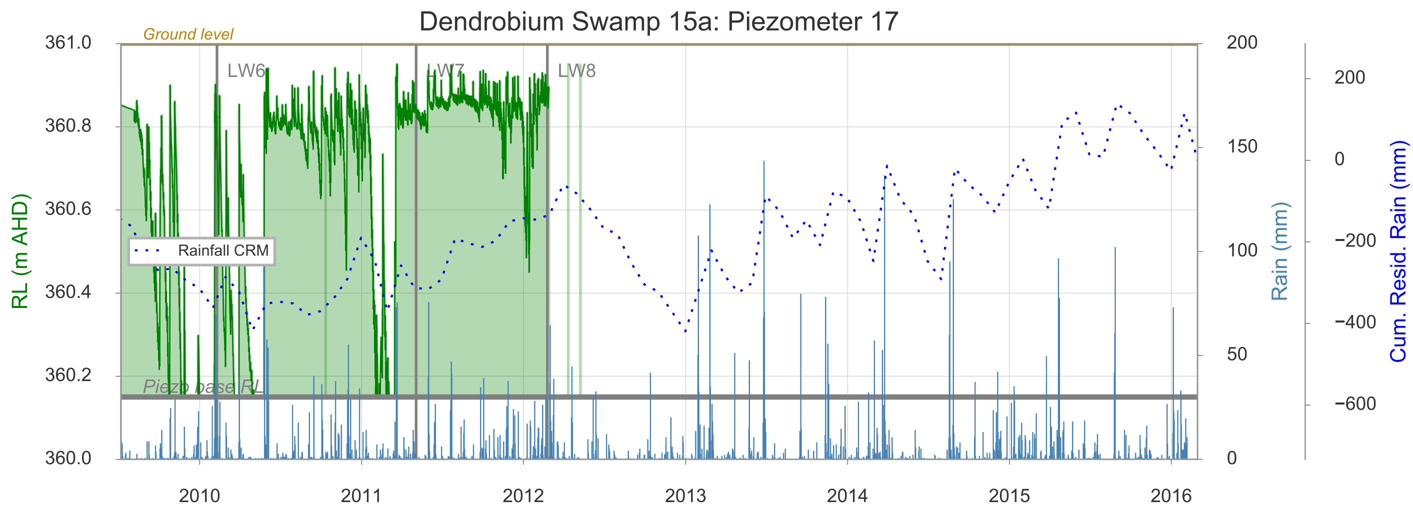

Dendrobium Swamp 14: Piezometer 01
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
Ground level
Piezo base RL
Rainfall CRM
Jul 2015
Aug 2015
Sep 2015
Oct 2015
Nov 2015
Dec 2015
Jan 2016
Feb 2016

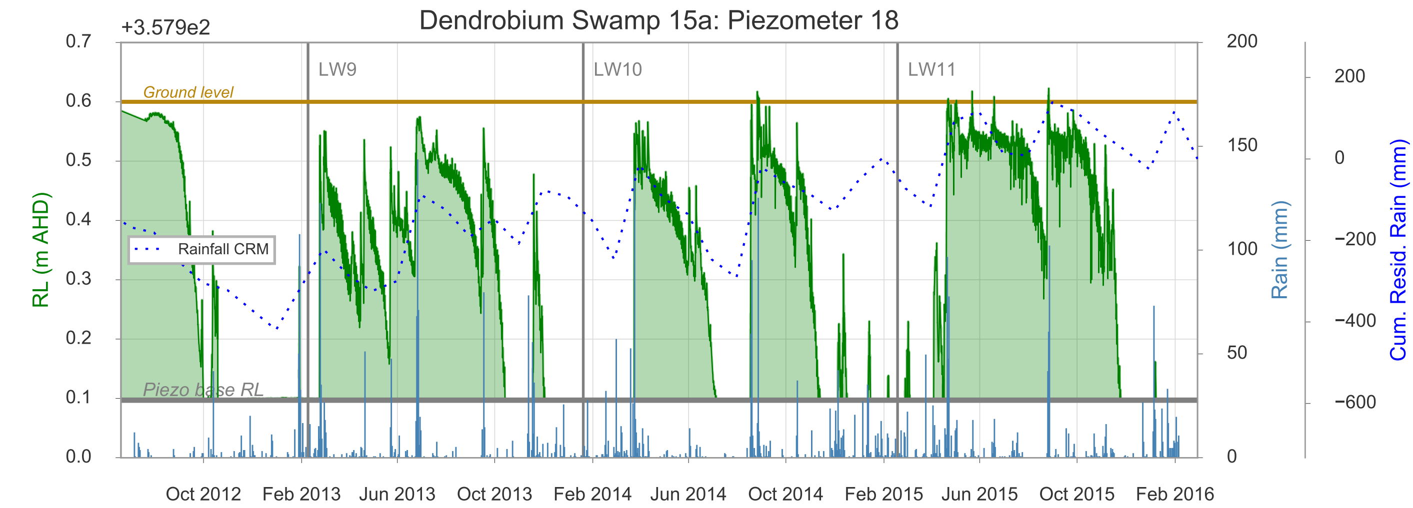

Dendrobium Swamp 14: Piezometer 02
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
Ground level
Piezo base RL
Rainfall CRM
Jul 2015
Aug 2015
Sep 2015
Oct 2015
Nov 2015
Dec 2015
Jan 2016
Feb 2016

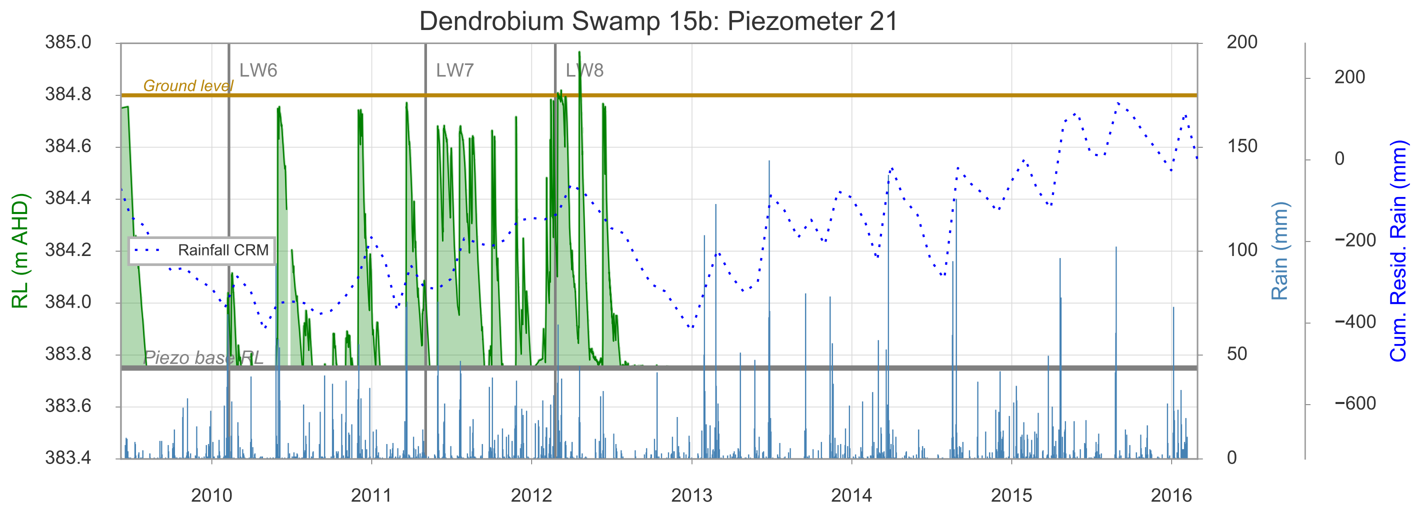

Dendrobium Swamp 15a: Piezometer 03
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
LW6
LW7
LW8
Ground level
Piezo base RL
Rainfall CRM
2010
2011
2012
2013
2014
2015
2016

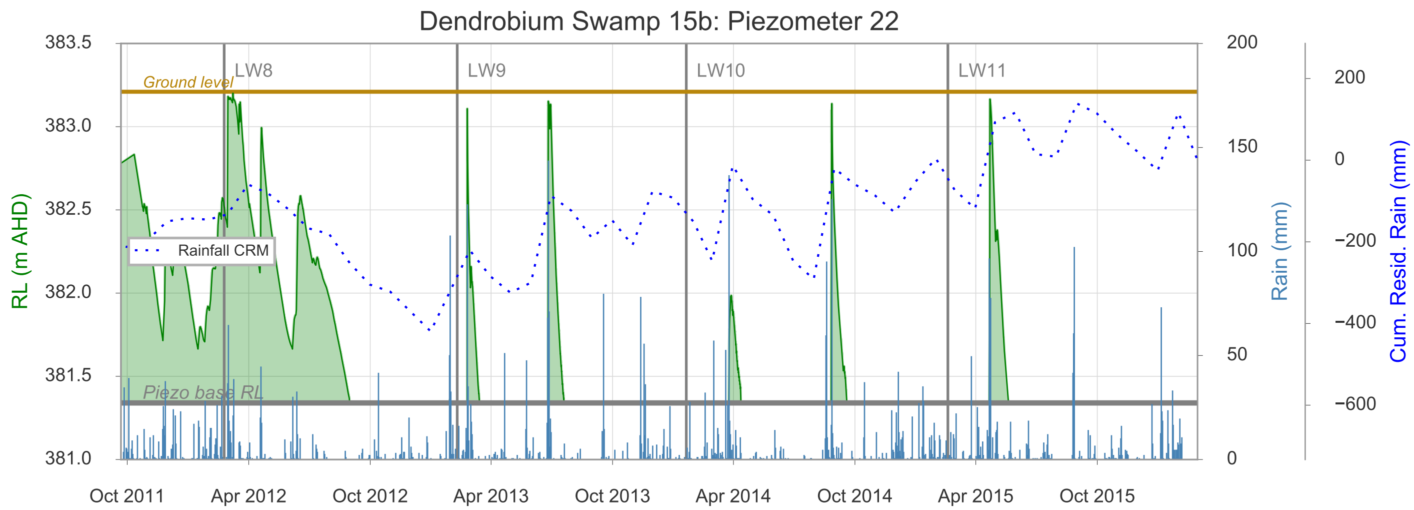

Dendrobium Swamp 15a: Piezometer 06
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
LW9
LW10
LW11
Ground level
Piezo base RL
Rainfall CRM
Oct 2012
Feb 2013
Jun 2013
Oct 2013
Feb 2014
Jun 2014
Oct 2014
Feb 2015
Jun 2015
Oct 2015
Feb 2016

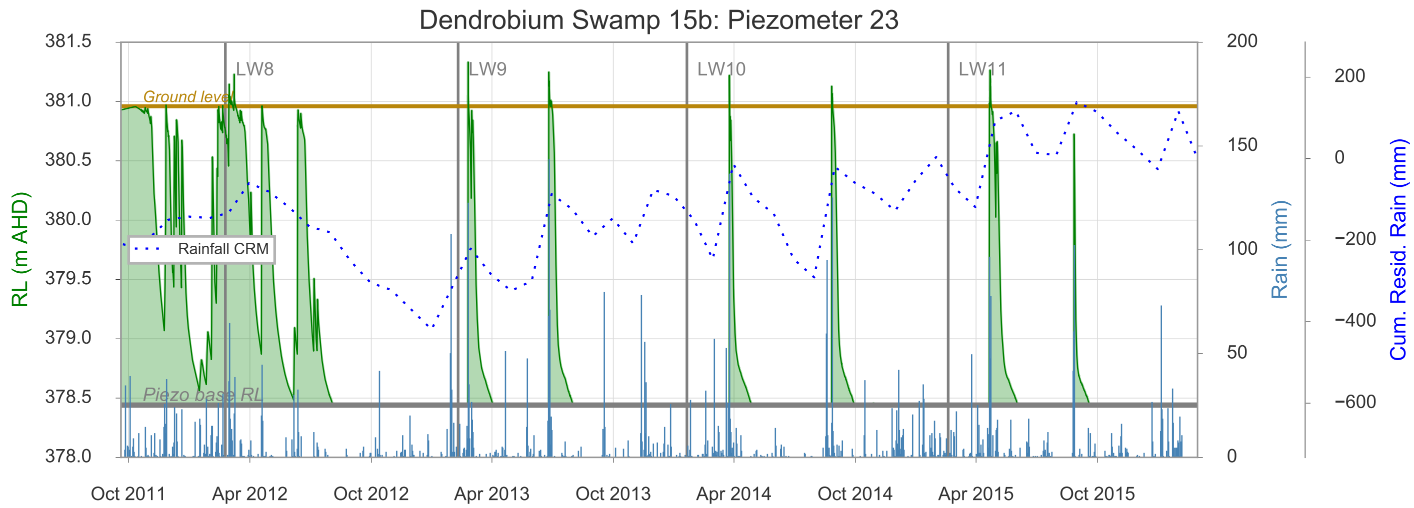

Dendrobium Swamp 15a: Piezometer 07
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
Ground level
Piezo base RL
Rainfall CRM
LW9
LW10
LW11
Oct 2012
Feb 2013
Jun 2013
Oct 2013
Feb 2014
Jun 2014
Oct 2014
Feb 2015
Jun 2015
Oct 2015
Feb 2016

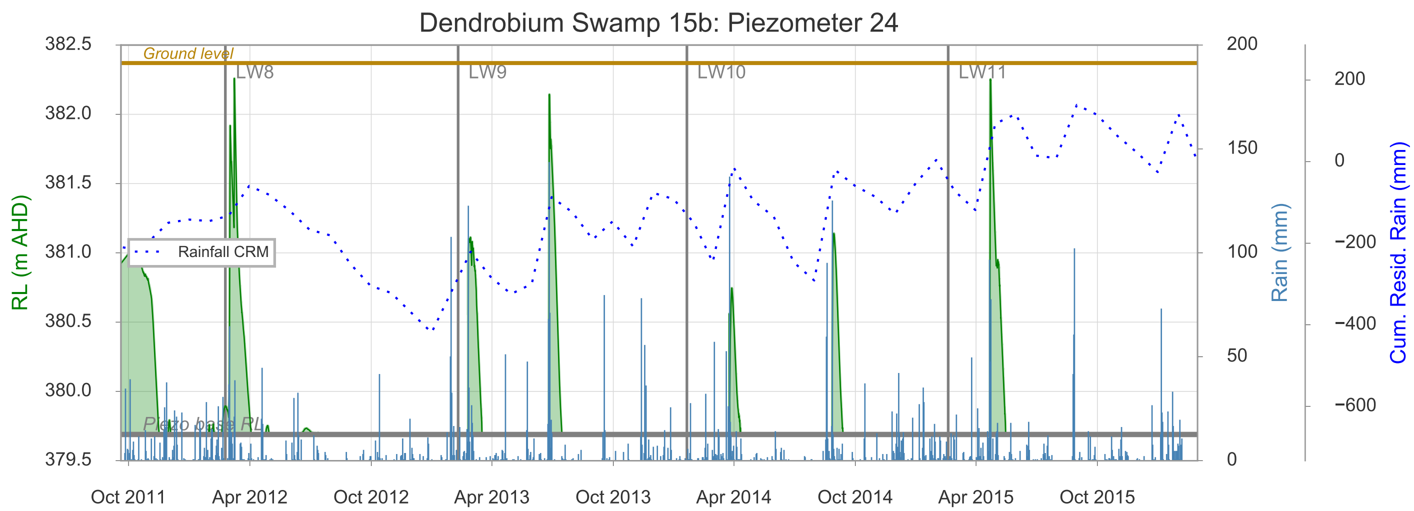

Dendrobium Swamp 15a: Piezometer 17
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
Ground level
Piezo base RL
Rainfall CRM
LW6
LW7
LW8
2010
2011
2012
2013
2014
2015
2016

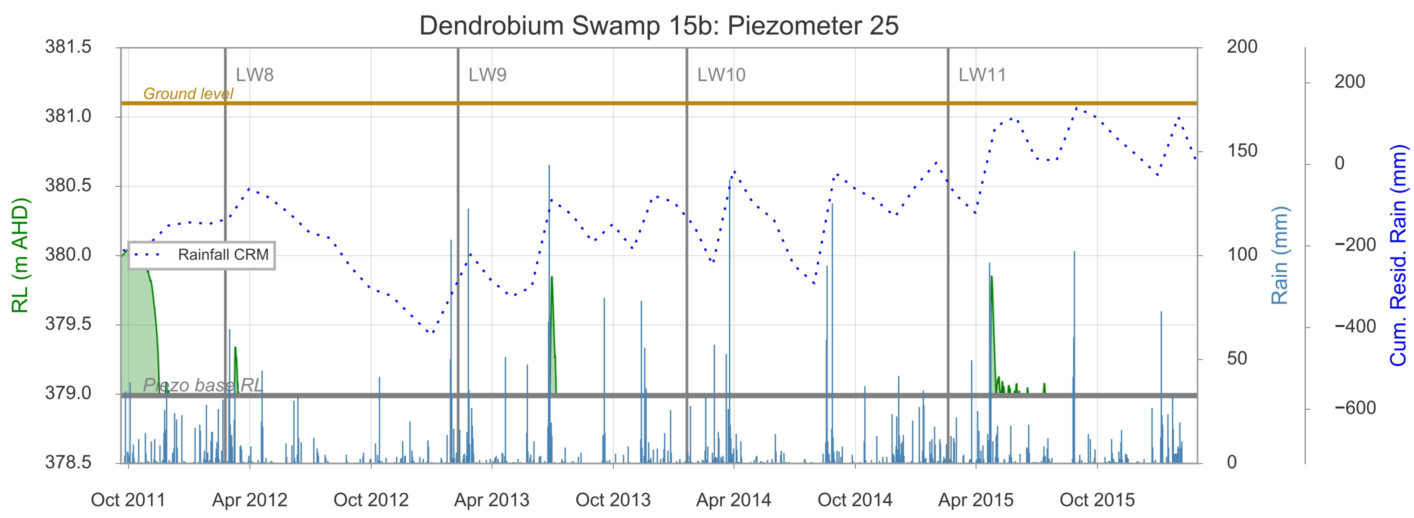

Dendrobium Swamp 15a: Piezometer 18
+3.579e2
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
Ground level
Piezo base RL
Rainfall CRM
LW9
LW10
LW11
Oct 2012
Feb 2013
Jun 2013
Oct 2013
Feb 2014
Jun 2014
Oct 2014
Feb 2015
Jun 2015
Oct 2015
Feb 2016

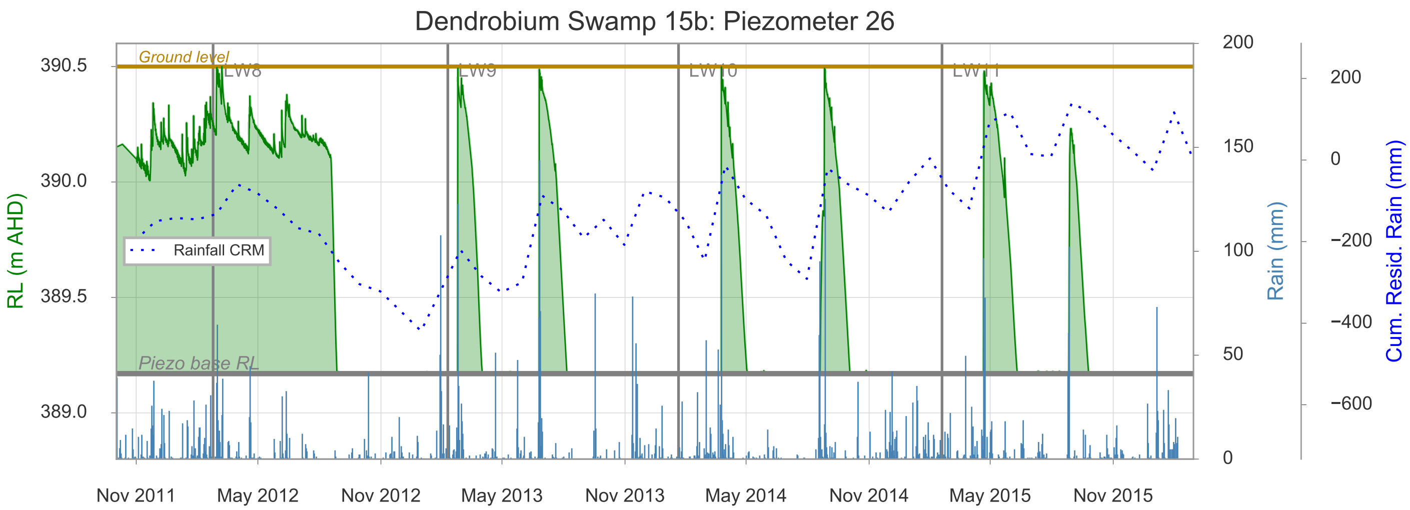

Dendrobium Swamp 15b: Piezometer 21
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
Ground level
Piezo base RL
Rainfall CRM
LW6
LW7
LW8
2010
2011
2012
2013
2014
2015
2016

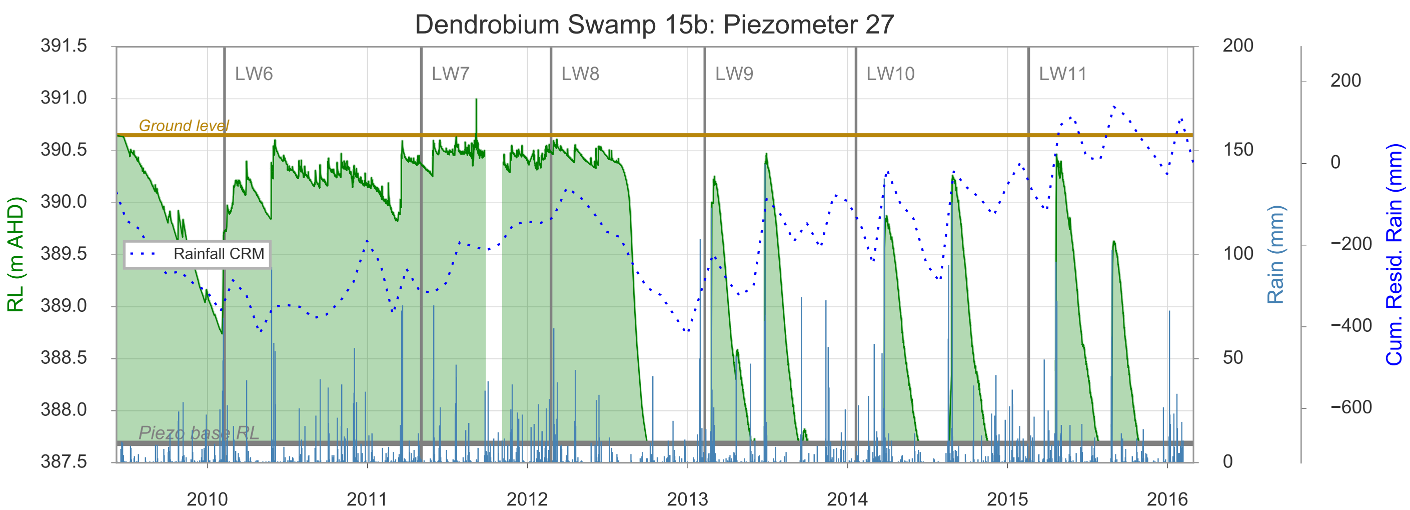

Dendrobium Swamp 15b: Piezometer 22
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
Rainfall CRM
Ground level
Piezo base RL
LW8
LW9
LW10
LW11
383.5
383.0
382.5
382.0
381.5
381.0
200
150
100
50
0
200
0
−200
−400
−600
Oct 2011
Apr 2012
Oct 2012
Apr 2013
Oct 2013
Apr 2014
Oct 2014
Apr 2015
Oct 2015

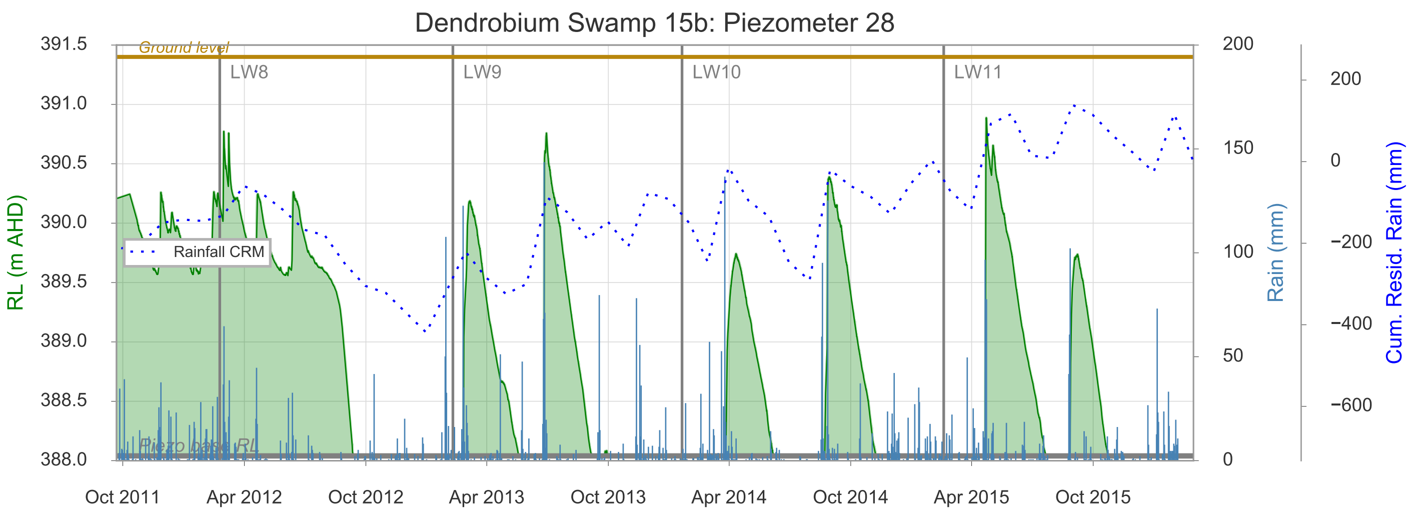

Dendrobium Swamp 15b: Piezometer 23
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
Rainfall CRM
Ground level
Piezo base RL
LW8
LW9
LW10
LW11
381.5
381.0
380.5
380.0
379.5
379.0
378.5
378.0
200
150
100
50
0
200
0
−200
−400
−600
Oct 2011
Apr 2012
Oct 2012
Apr 2013
Oct 2013
Apr 2014
Oct 2014
Apr 2015
Oct 2015

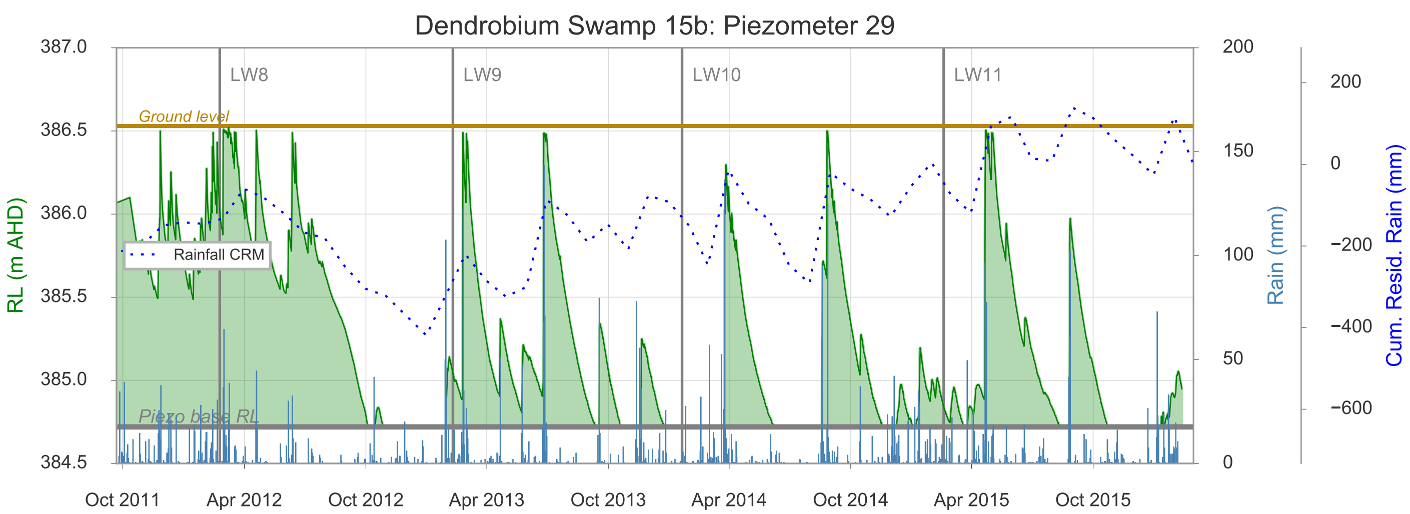

Dendrobium Swamp 15b: Piezometer 24
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
Rainfall CRM
Ground level
Piezo base RL
LW8
LW9
LW10
LW11
382.5
382.0
381.5
381.0
380.5
380.0
379.5
200
150
100
50
0
200
0
−200
−400
−600
Oct 2011
Apr 2012
Oct 2012
Apr 2013
Oct 2013
Apr 2014
Oct 2014
Apr 2015
Oct 2015

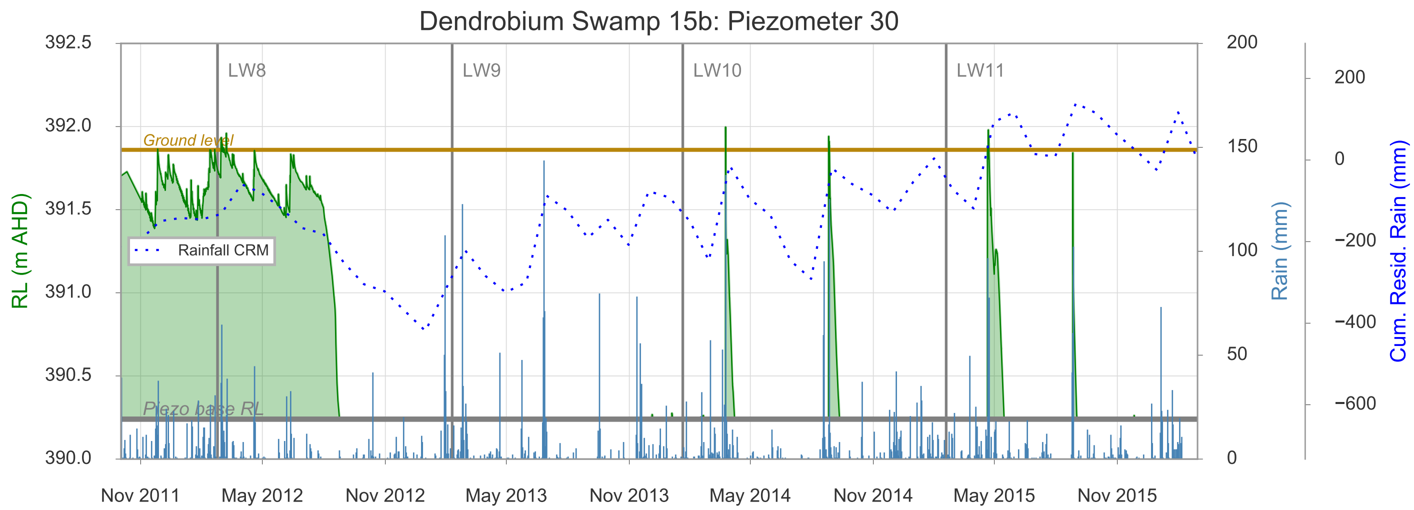

Dendrobium Swamp 15b: Piezometer 25
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
Rainfall CRM
Ground level
Piezo base RL
LW8
LW9
LW10
LW11
381.5
381.0
380.5
380.0
379.5
379.0
378.5
200
150
100
50
0
200
0
−200
−400
−600
Oct 2011
Apr 2012
Oct 2012
Apr 2013
Oct 2013
Apr 2014
Oct 2014
Apr 2015
Oct 2015

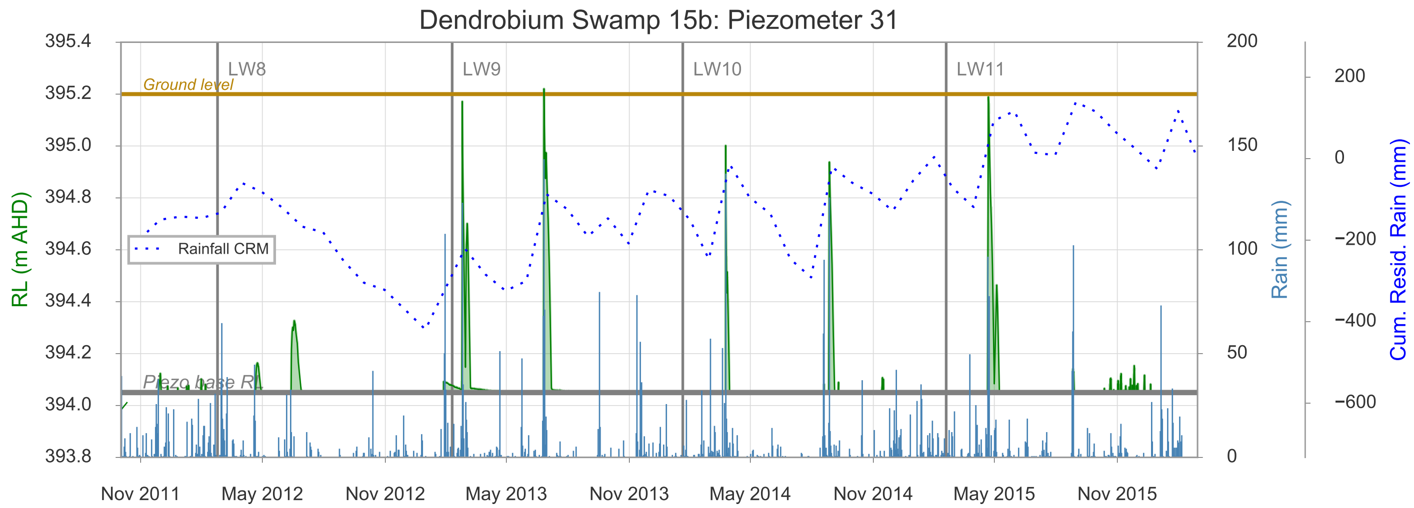

Dendrobium Swamp 15b: Piezometer 26
Ground level
LW8
LW9
LW10
LW11
Rainfall CRM
Piezo base RL
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
390.5
390.0
389.5
389.0
200
150
100
50
0
200
0
−200
−400
−600
Nov 2011
May 2012
Nov 2012
May 2013
Nov 2013
May 2014
Nov 2014
May 2015
Nov 2015

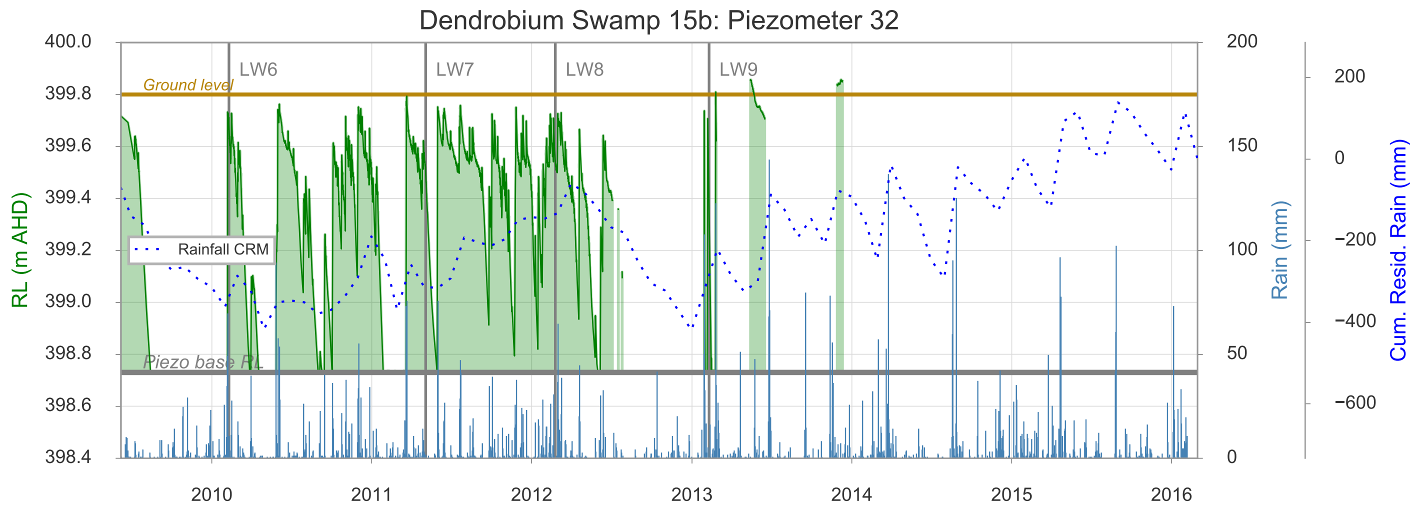

Dendrobium Swamp 15b: Piezometer 27
Ground level
LW6
LW7
LW8
LW9
LW10
LW11
Rainfall CRM
Piezo base RL
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
391.5
391.0
390.5
390.0
389.5
389.0
388.5
388.0
387.5
200
150
100
50
0
200
0
−200
−400
−600
2010
2011
2012
2013
2014
2015
2016

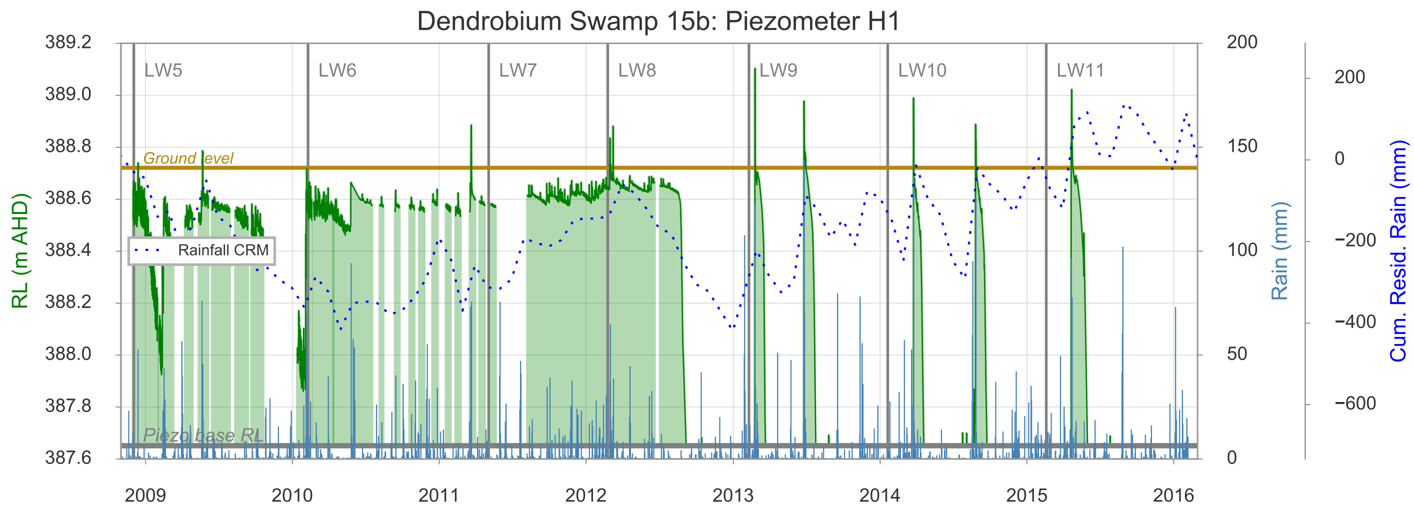

Dendrobium Swamp 15b: Piezometer 28
Ground level
LW8
LW9
LW10
LW11
Rainfall CRM
Piezo base RL
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
391.5
391.0
390.5
390.0
389.5
389.0
388.5
388.0
200
150
100
50
0
200
0
−200
−400
−600
Oct 2011
Apr 2012
Oct 2012
Apr 2013
Oct 2013
Apr 2014
Oct 2014
Apr 2015
Oct 2015

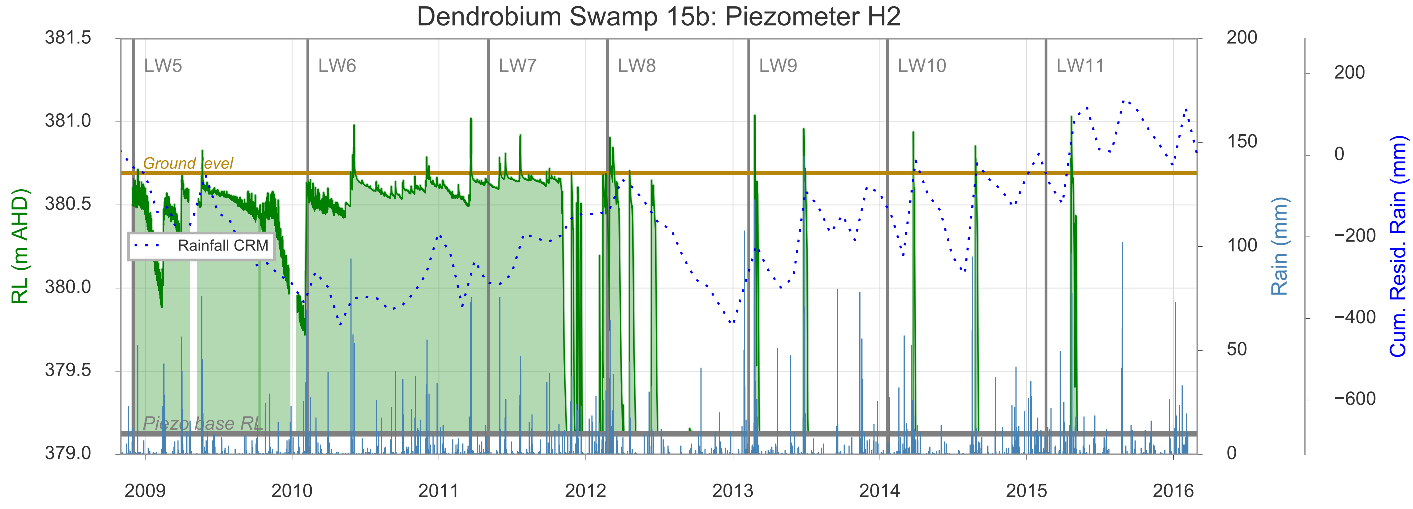

Dendrobium Swamp 15b: Piezometer 29
Ground level
LW8
LW9
LW10
LW11
Rainfall CRM
Piezo base RL
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
387.0
386.5
386.0
385.5
385.0
384.5
200
150
100
50
0
200
0
−200
−400
−600
Oct 2011
Apr 2012
Oct 2012
Apr 2013
Oct 2013
Apr 2014
Oct 2014
Apr 2015
Oct 2015

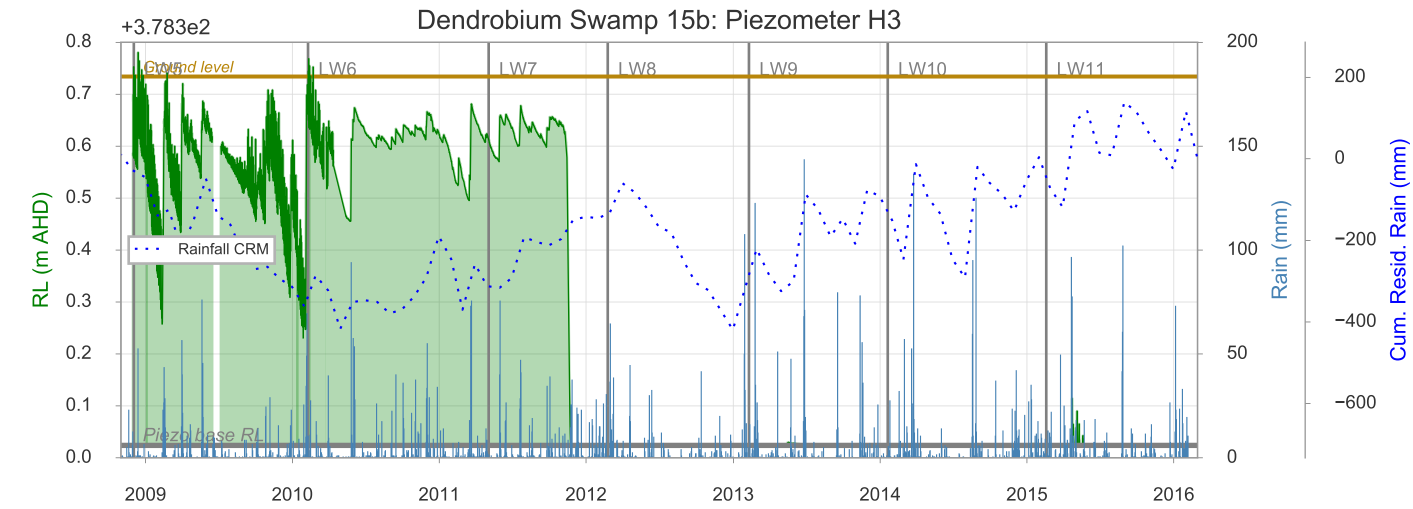

Dendrobium Swamp 15b: Piezometer 30
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
Rainfall CRM
Ground level
Piezo base RL
LW8
LW9
LW10
LW11
Nov 2011
May 2012
Nov 2012
May 2013
Nov 2013
May 2014
Nov 2014
May 2015
Nov 2015

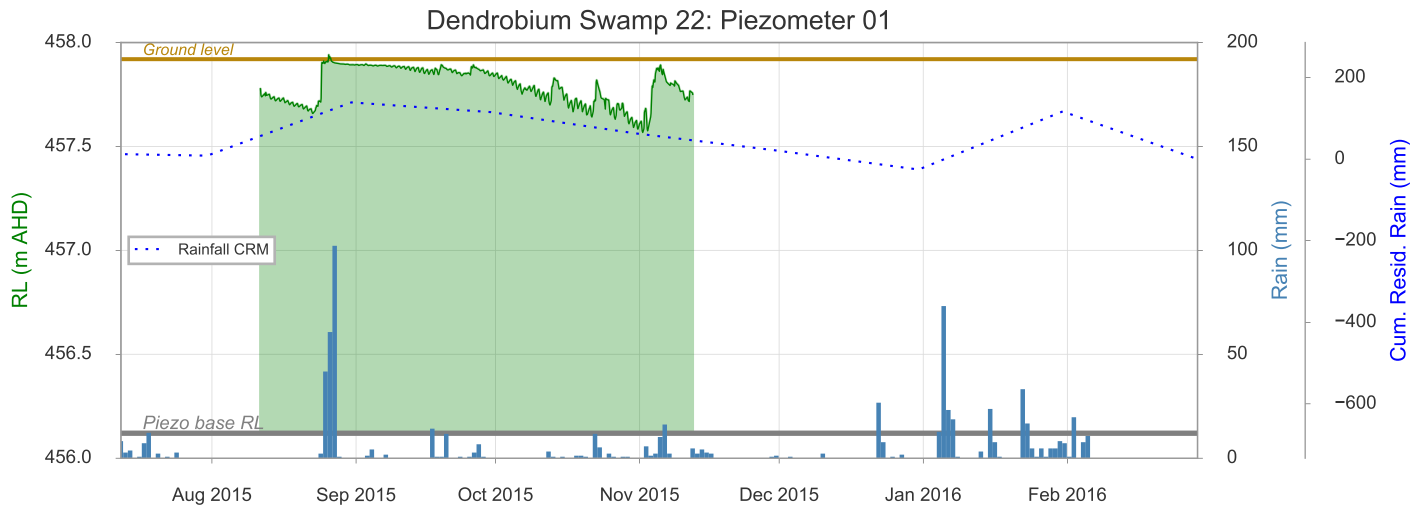

Dendrobium Swamp 15b: Piezometer 31
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
Rainfall CRM
Ground level
Piezo base RL
LW8
LW9
LW10
LW11
Nov 2011
May 2012
Nov 2012
May 2013
Nov 2013
May 2014
Nov 2014
May 2015
Nov 2015

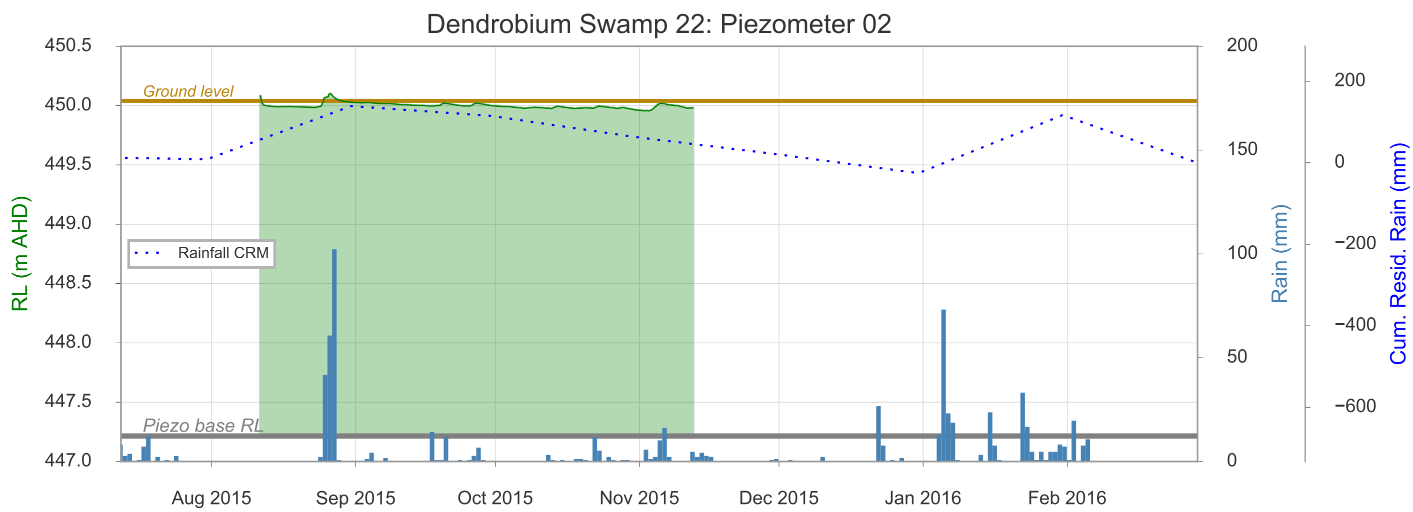

Dendrobium Swamp 15b: Piezometer 32
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
Rainfall CRM
Ground level
Piezo base RL
LW6
LW7
LW8
LW9
2010
2011
2012
2013
2014
2015
2016

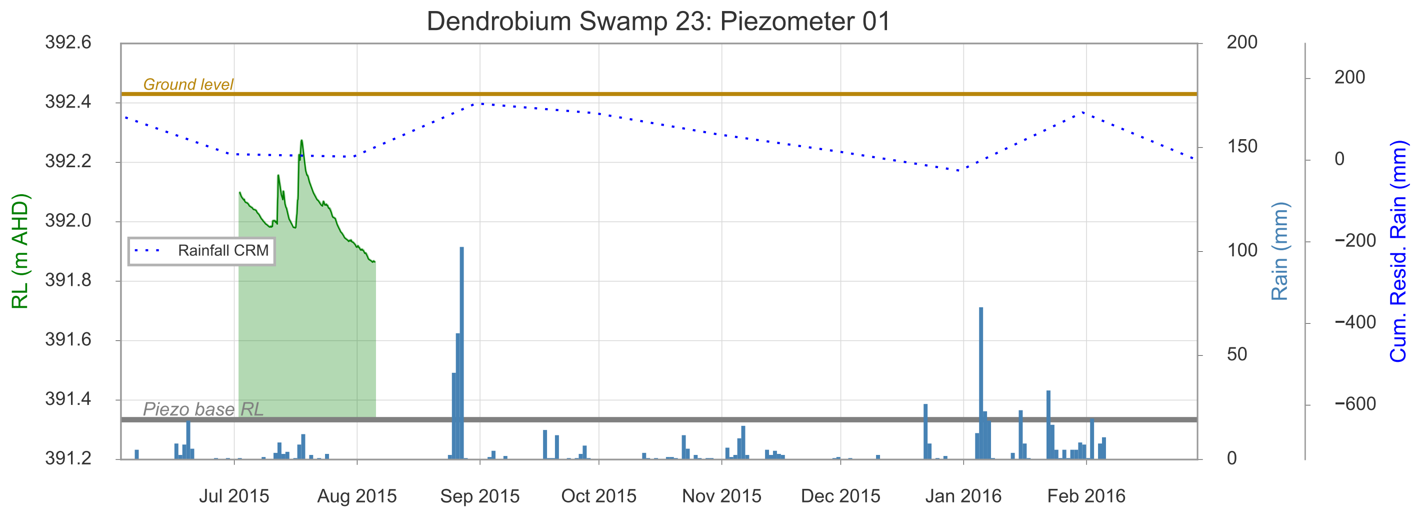

Dendrobium Swamp 15b: Piezometer H1
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
Rainfall CRM
Ground level
Piezo base RL
LW5
LW6
LW7
LW8
LW9
LW10
LW11
2009
2010
2011
2012
2013
2014
2015
2016


Dendrobium Swamp 15b: Piezometer H2
LW5
LW6
LW7
LW8
LW9
LW10
LW11
Ground level
Rainfall CRM
Piezo base RL
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
381.5
381.0
380.5
380.0
379.5
379.0
2009
2010
2011
2012
2013
2014
2015
2016

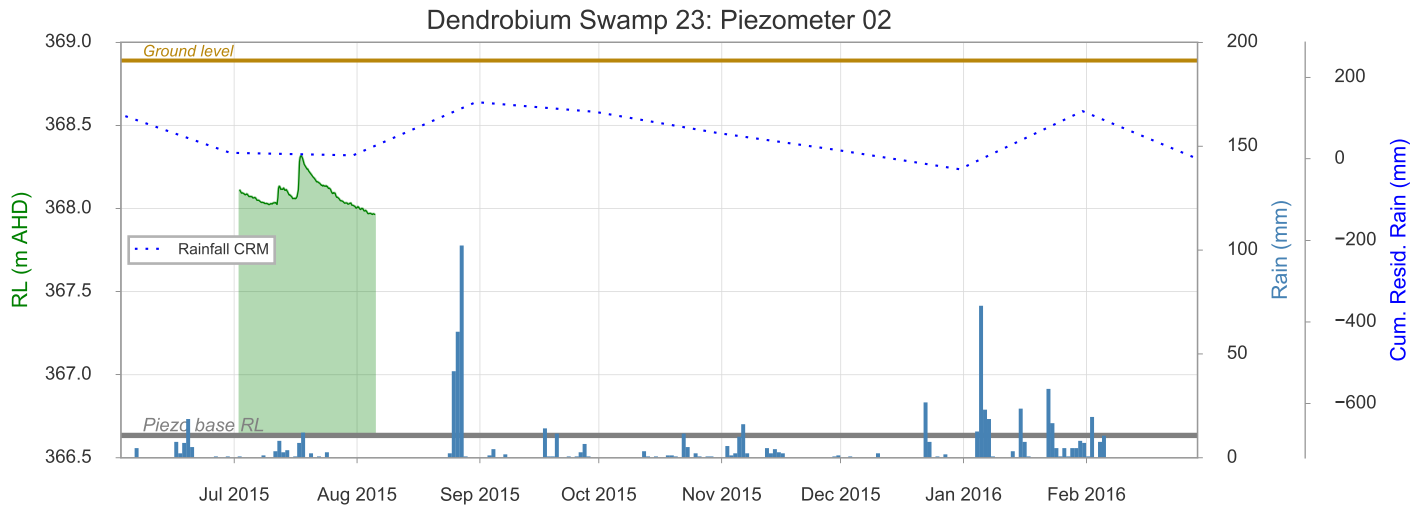

Dendrobium Swamp 15b: Piezometer H3
+3.783e2
LW6
LW7
LW8
LW9
LW10
LW11
Ground level
Rainfall CRM
Piezo base RL
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
2009
2010
2011
2012
2013
2014
2015
2016


Dendrobium Swamp 22: Piezometer 01
Ground level
Rainfall CRM
Piezo base RL
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
458.0
457.5
457.0
456.5
456.0
Aug 2015
Sep 2015
Oct 2015
Nov 2015
Dec 2015
Jan 2016
Feb 2016

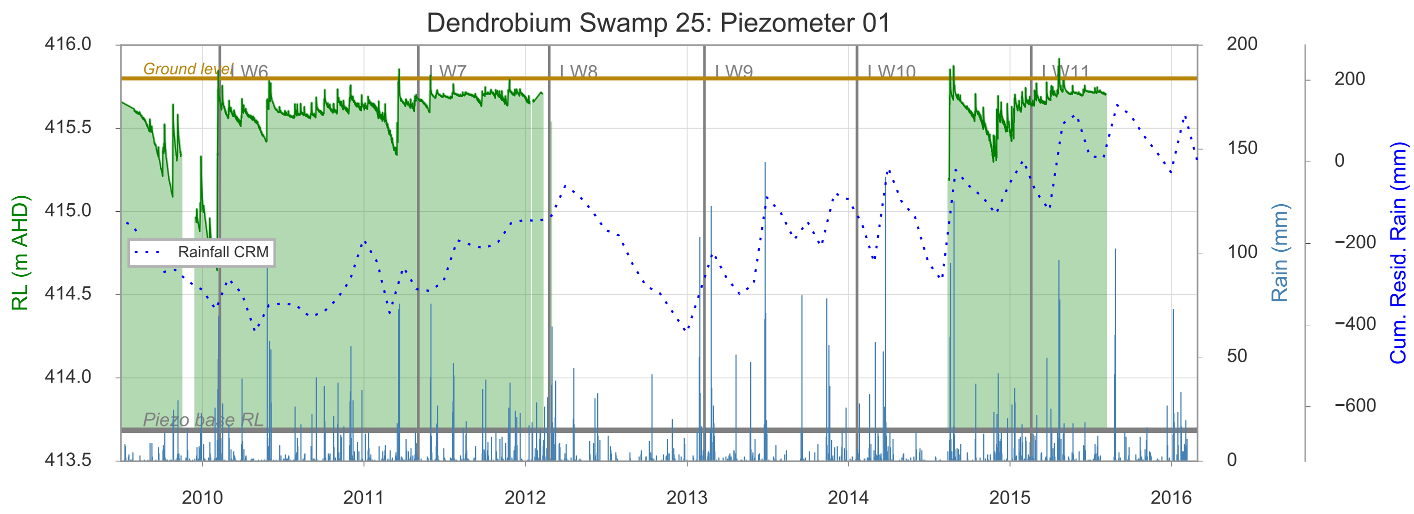

Dendrobium Swamp 22: Piezometer 02
Ground level
Rainfall CRM
Piezo base RL
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
450.5
450.0
449.5
449.0
448.5
448.0
447.5
447.0
Aug 2015
Sep 2015
Oct 2015
Nov 2015
Dec 2015
Jan 2016
Feb 2016



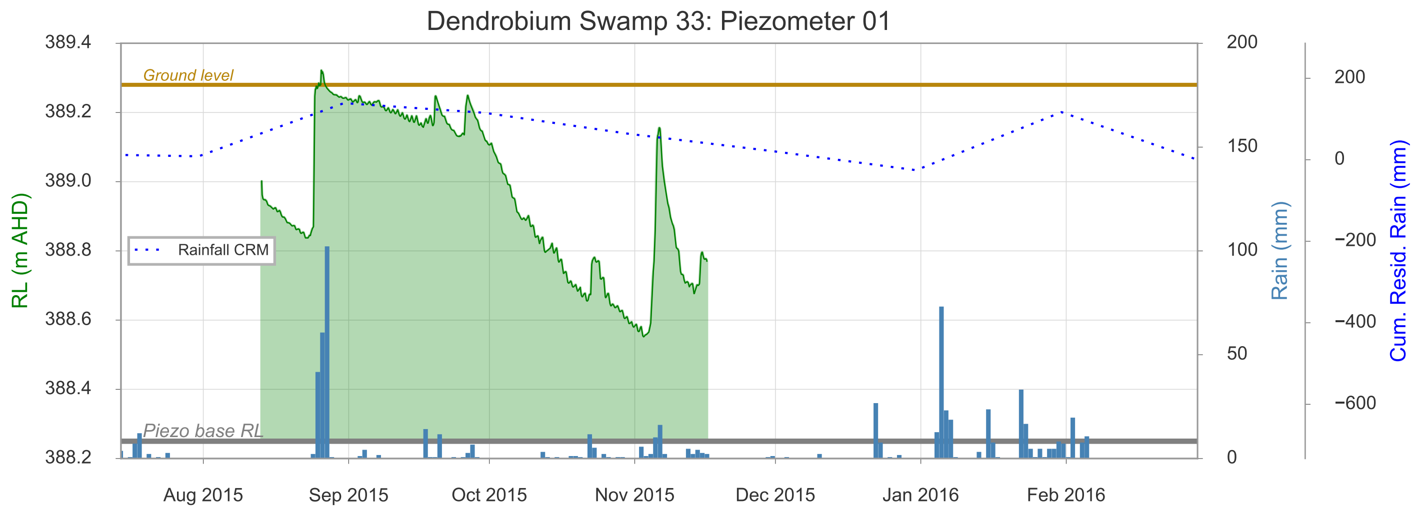
Dendrobium Swamp 23: Piezometer 01
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
Ground level
Piezo base RL
Rainfall CRM
392.6
392.4
392.2
392.0
391.8
391.6
391.4
391.2
200
150
100
50
0
-200
-400
-600
Jul 2015
Aug 2015
Sep 2015
Oct 2015
Nov 2015
Dec 2015
Jan 2016
Feb 2016



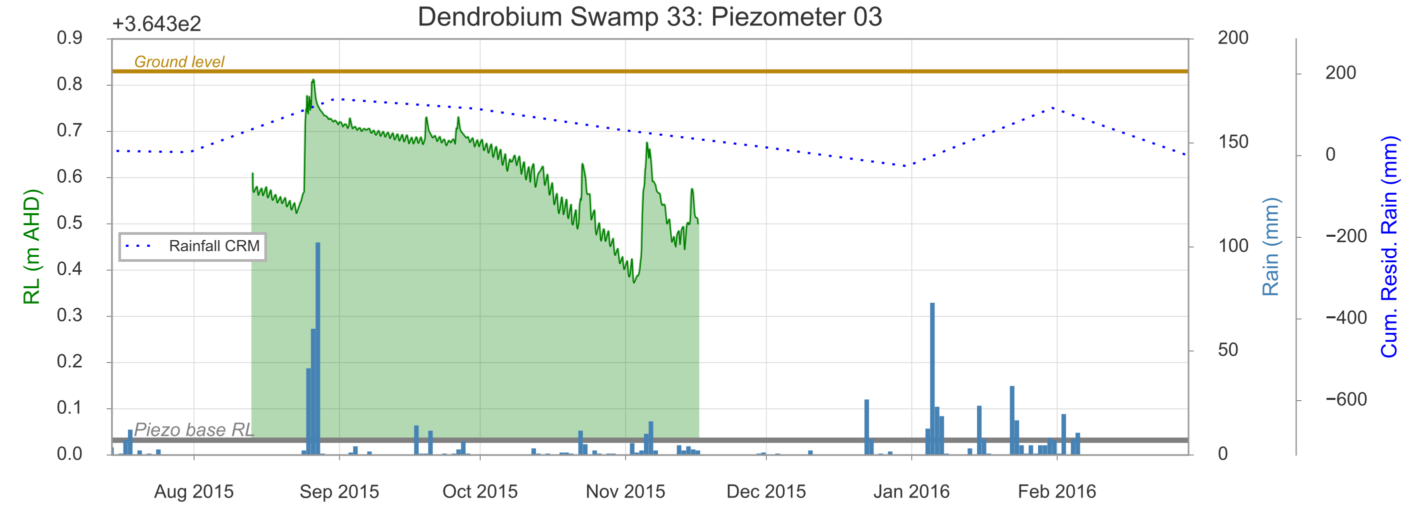
Dendrobium Swamp 23: Piezometer 02
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
Ground level
Piezo base RL
Rainfall CRM
369.0
368.5
368.0
367.5
367.0
366.5
200
150
100
50
0
-200
-400
-600
Jul 2015
Aug 2015
Sep 2015
Oct 2015
Nov 2015
Dec 2015
Jan 2016
Feb 2016



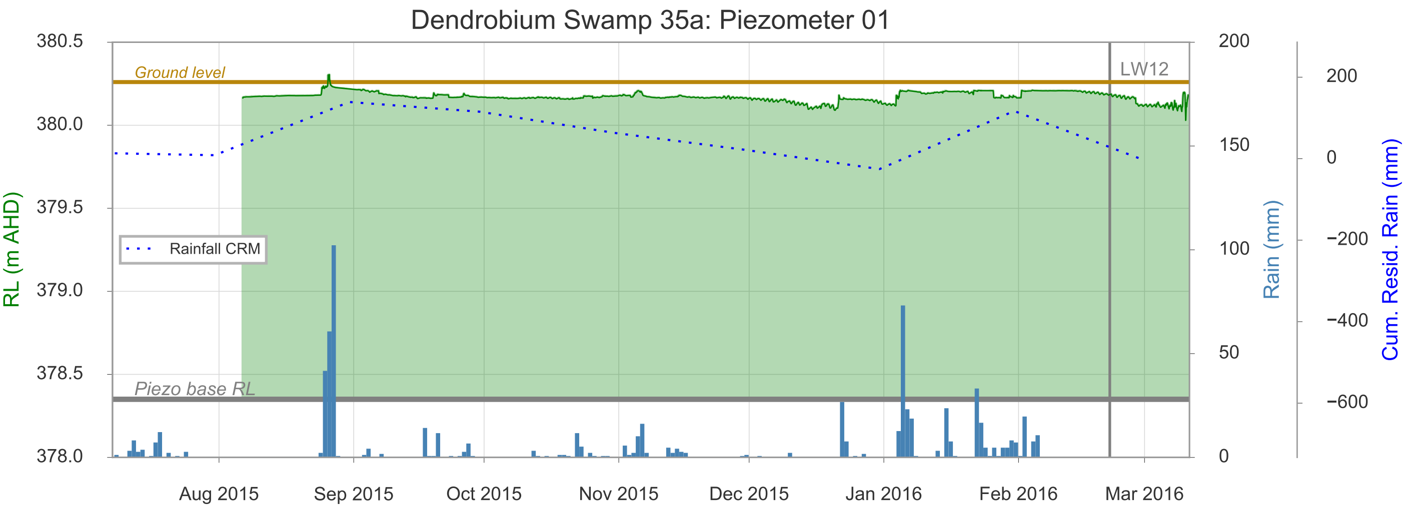
Dendrobium Swamp 25: Piezometer 01
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
Ground level
Piezo base RL
Rainfall CRM
LW6
LW7
LW8
LW9
LW10
LW11
416.0
415.5
415.0
414.5
414.0
413.5
200
150
100
50
0
-200
-400
-600
2010
2011
2012
2013
2014
2015
2016



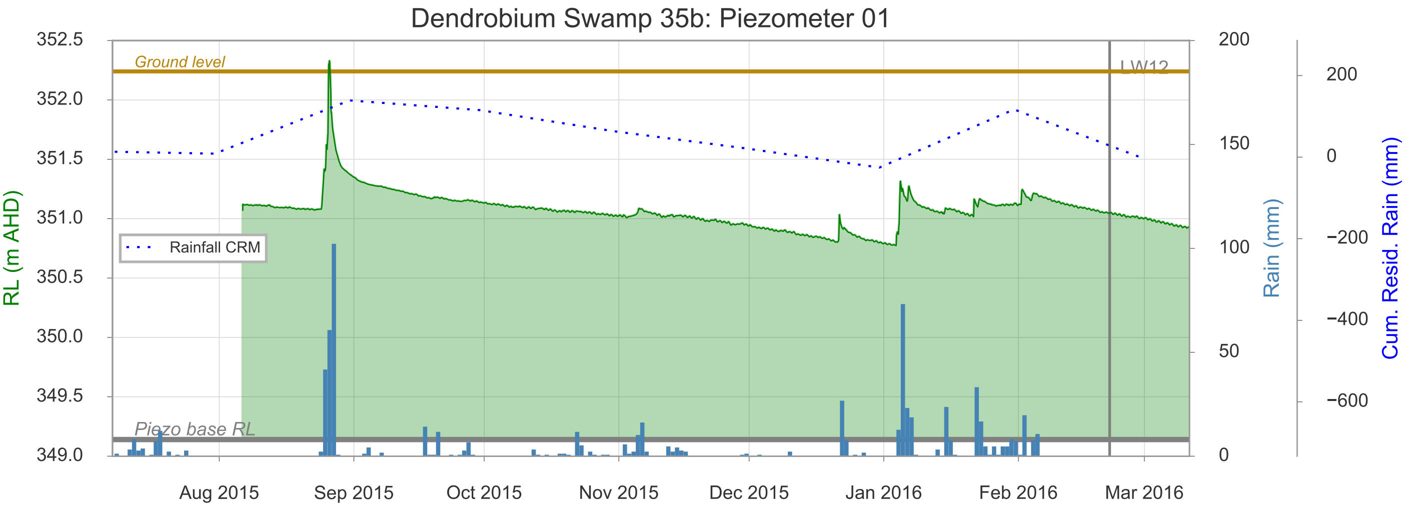
Dendrobium Swamp 33: Piezometer 01
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
Ground level
Piezo base RL
Rainfall CRM
389.4
389.2
389.0
388.8
388.6
388.4
388.2
200
150
100
50
0
-200
-400
-600
Aug 2015
Sep 2015
Oct 2015
Nov 2015
Dec 2015
Jan 2016
Feb 2016



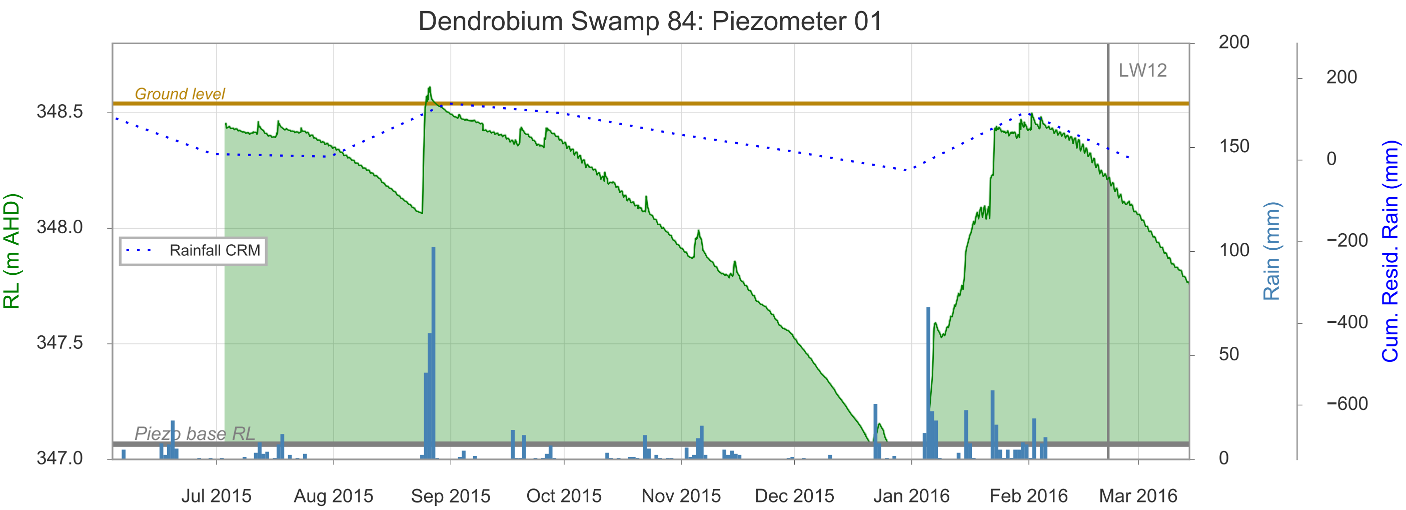
Dendrobium Swamp 33: Piezometer 03
+3.643e2
Ground level
Piezo base RL
Rainfall CRM
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
200
150
100
50
0
200
0
−200
−400
−600
Aug 2015
Sep 2015
Oct 2015
Nov 2015
Dec 2015
Jan 2016
Feb 2016



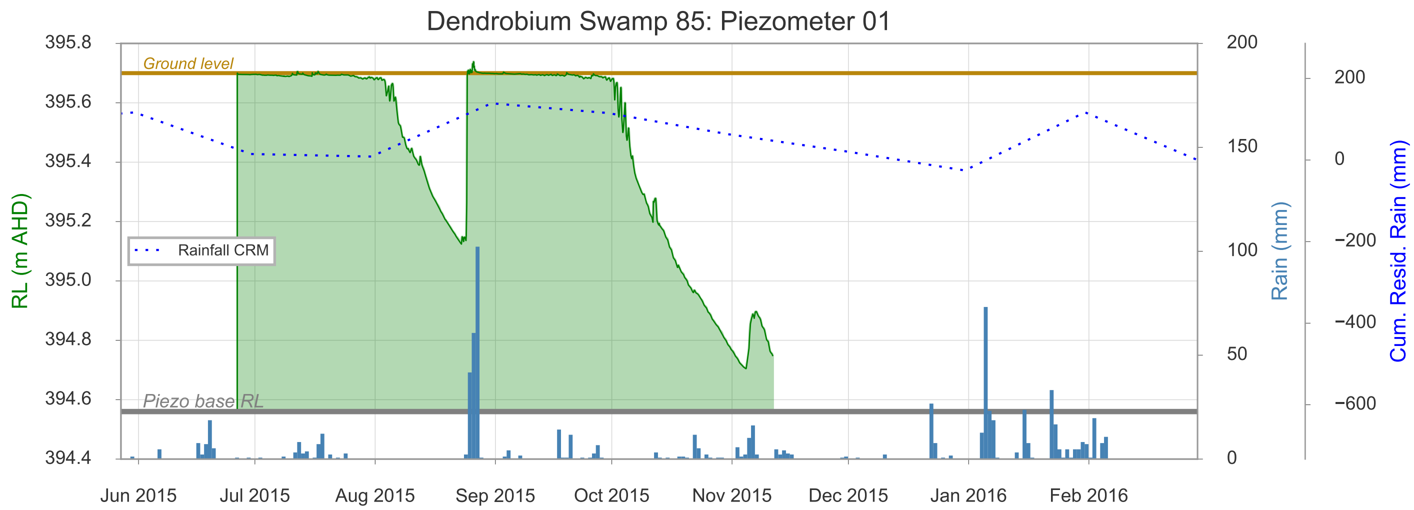
Dendrobium Swamp 35a: Piezometer 01
Ground level
Piezo base RL
Rainfall CRM
LW12
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
380.5
380.0
379.5
379.0
378.5
378.0
200
150
100
50
0
200
0
−200
−400
−600
Aug 2015
Sep 2015
Oct 2015
Nov 2015
Dec 2015
Jan 2016
Feb 2016
Mar 2016

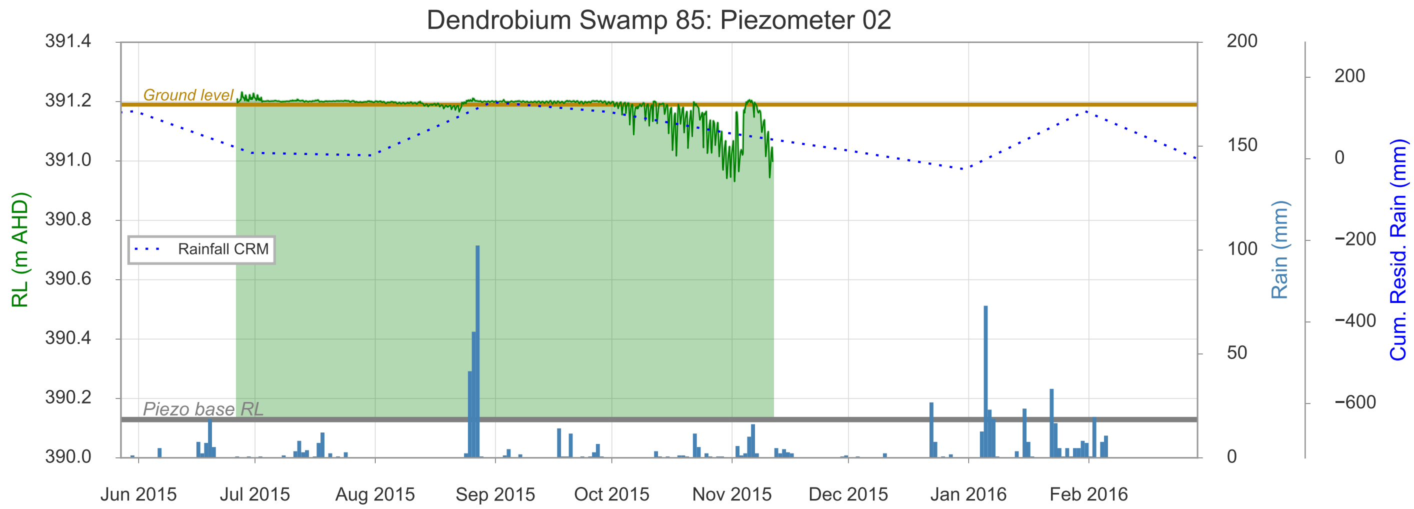


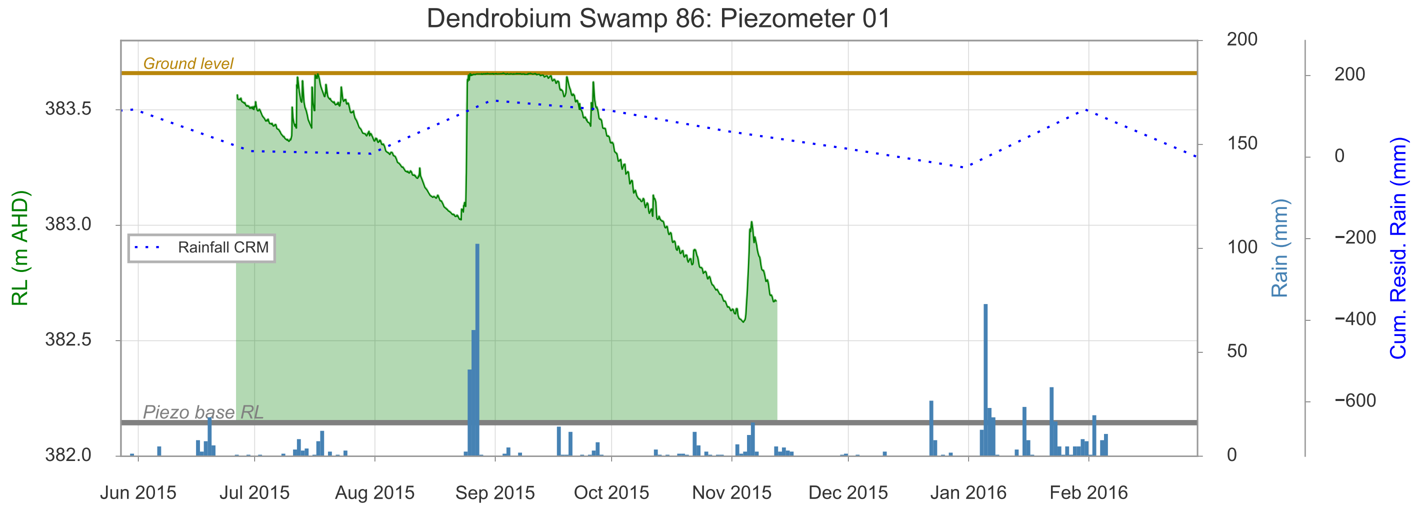
Dendrobium Swamp 35b: Piezometer 01
Ground level
Piezo base RL
Rainfall CRM
LW12
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
352.5
352.0
351.5
351.0
350.5
350.0
349.5
349.0
200
150
100
50
0
200
0
−200
−400
−600
Aug 2015
Sep 2015
Oct 2015
Nov 2015
Dec 2015
Jan 2016
Feb 2016
Mar 2016

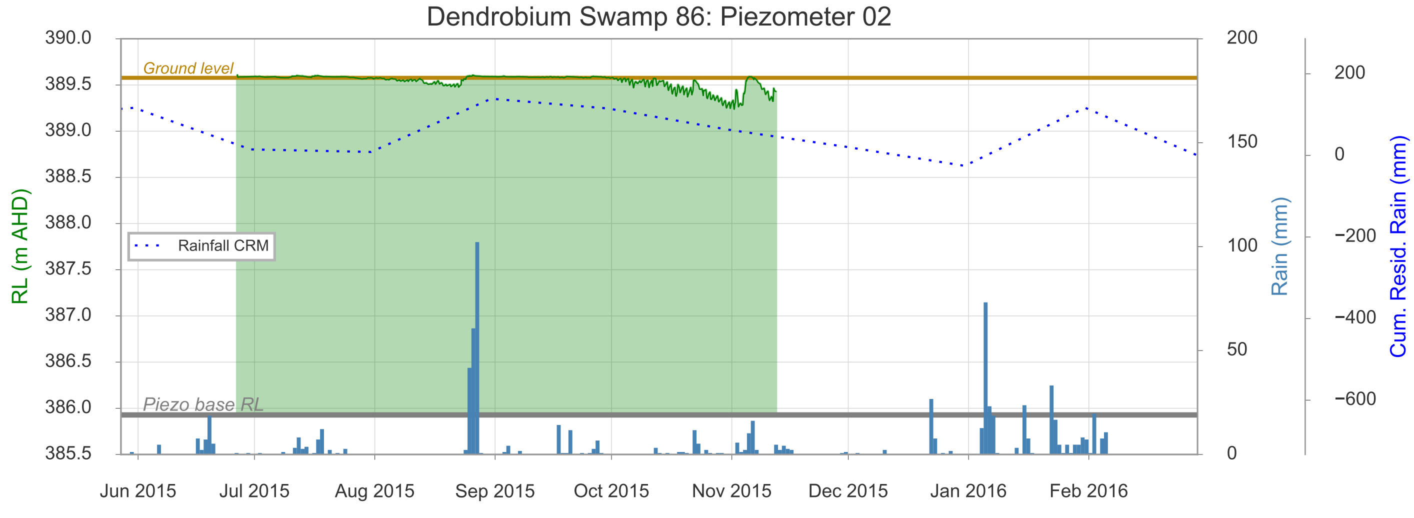


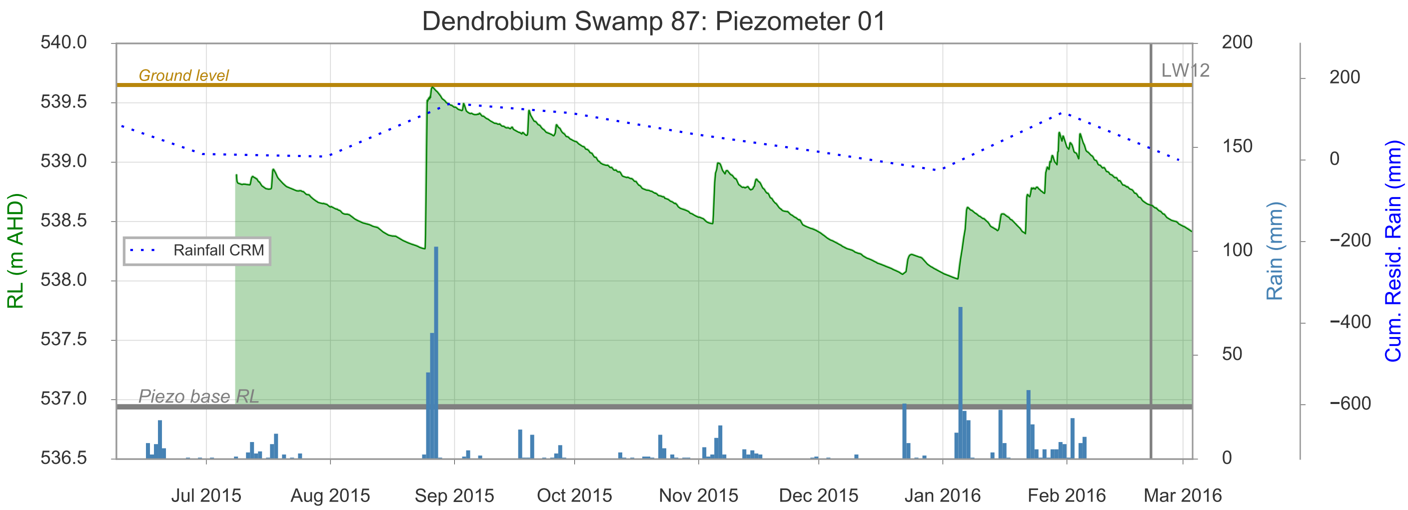
Dendrobium Swamp 84: Piezometer 01
Ground level
Piezo base RL
Rainfall CRM
LW12
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
348.5
348.0
347.5
347.0
200
150
100
50
0
200
0
−200
−400
−600
Jul 2015
Aug 2015
Sep 2015
Oct 2015
Nov 2015
Dec 2015
Jan 2016
Feb 2016
Mar 2016

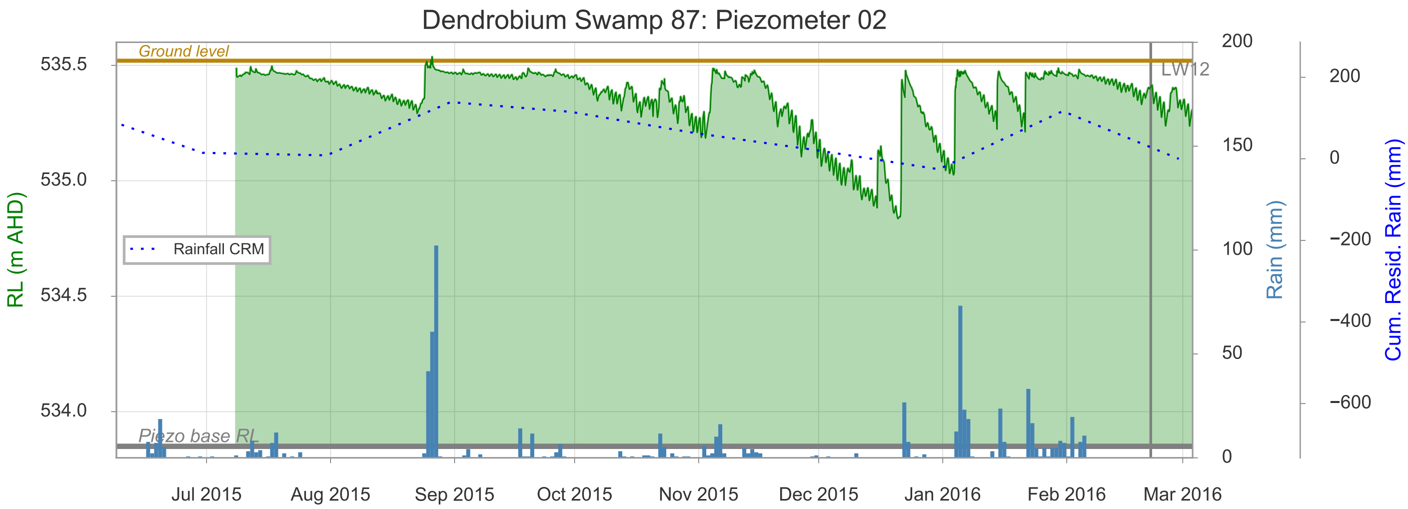

Dendrobium Swamp 85: Piezometer 01
Ground level
Piezo base RL
Rainfall CRM
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
Jun 2015
Jul 2015
Aug 2015
Sep 2015
Oct 2015
Nov 2015
Dec 2015
Jan 2016
Feb 2016

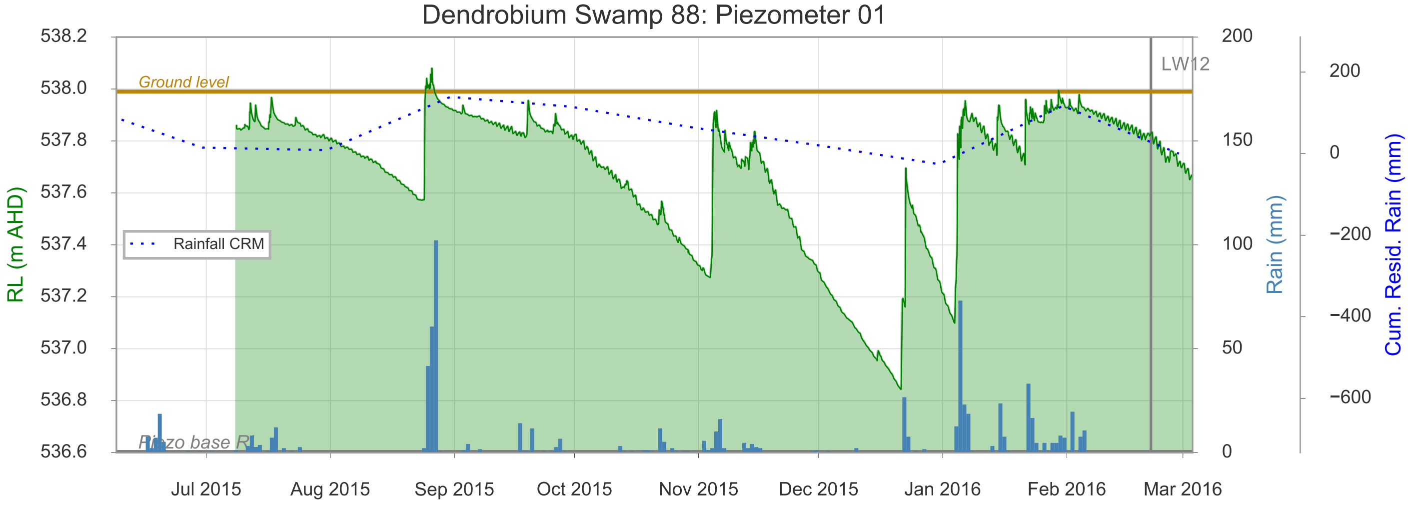

Dendrobium Swamp 85: Piezometer 02
Ground level
Piezo base RL
Rainfall CRM
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
Jun 2015
Jul 2015
Aug 2015
Sep 2015
Oct 2015
Nov 2015
Dec 2015
Jan 2016
Feb 2016

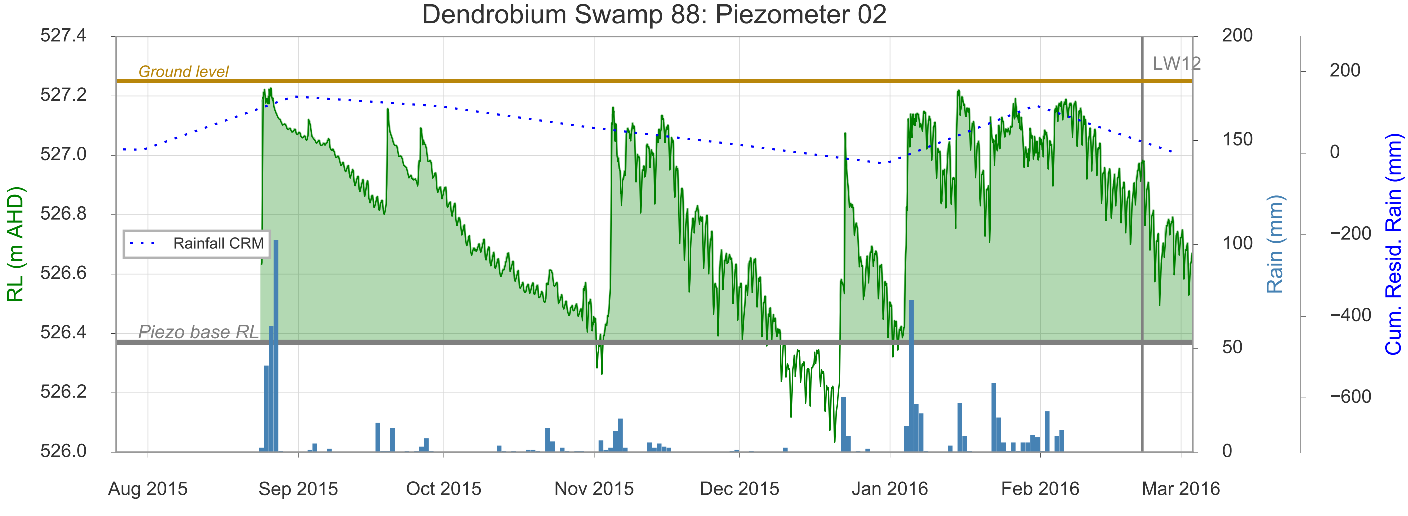

Dendrobium Swamp 86: Piezometer 01
Ground level
Piezo base RL
Rainfall CRM
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
Jun 2015
Jul 2015
Aug 2015
Sep 2015
Oct 2015
Nov 2015
Dec 2015
Jan 2016
Feb 2016


Dendrobium Swamp 86: Piezometer 02
Ground level
Piezo base RL
Rainfall CRM
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
Jun 2015
Jul 2015
Aug 2015
Sep 2015
Oct 2015
Nov 2015
Dec 2015
Jan 2016
Feb 2016


Dendrobium Swamp 87: Piezometer 01
Ground level
Piezo base RL
LW12
Rainfall CRM
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
Jul 2015
Aug 2015
Sep 2015
Oct 2015
Nov 2015
Dec 2015
Jan 2016
Feb 2016
Mar 2016


Dendrobium Swamp 87: Piezometer 02
Ground level
Piezo base RL
LW12
Rainfall CRM
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
Jul 2015
Aug 2015
Sep 2015
Oct 2015
Nov 2015
Dec 2015
Jan 2016
Feb 2016
Mar 2016


Dendrobium Swamp 88: Piezometer 01
Ground level
Piezo base RL
LW12
Rainfall CRM
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
Jul 2015
Aug 2015
Sep 2015
Oct 2015
Nov 2015
Dec 2015
Jan 2016
Feb 2016
Mar 2016


Dendrobium Swamp 88: Piezometer 02
Ground level
Piezo base RL
LW12
Rainfall CRM
RL (m AHD)
Rain (mm)
Cum. Resid. Rain (mm)
Aug 2015
Sep 2015
Oct 2015
Nov 2015
Dec 2015
Jan 2016
Feb 2016
Mar 2016